This document was approved for publication at;
NRMSC 12 Canberra, 2 August 2006

REVIEW OF THE NATIONAL WEED RISK ASSESSMENT SYSTEM

Conducted by the NWRAS Review Group -

A Joint Natural Resource Management Standing Committee-Primary Industries Standing Committee Sub-committee

30 November 2005

CONTENTS

EXECUTIVE SUMMARY

The National Weed Risk Assessment (WRA) system, which was introduced by the Australian Government in 1997 following the Nairn Review, is a system for pre-screening material so that species with a low potential to become weeds can be imported while preventing the importation of species with a high potential to become weeds in Australian agricultural systems and/or the environment.

The WRA process is a three-tier system, and includes a science based scoring system to determine a score predicting the potential weediness of the plant being assessed. The score determines whether the plant is rejected, accepted, or subject to further evaluation.

Following seven years experience with this new system, the Primary Industries and Natural Resource Management Standing Committees agreed to a review of the system, following concerns raised by stakeholders regarding its practical operation.

The Review examines the current system, how it operates, and looks at some of the perceptions, issues and concerns that have been raised by stakeholders. These range from concern that our import restrictions are too lax, to a concern that the introduction of new plant species which could provide substantial benefit to both agriculture and the environment is being prevented.

The Review finds that, despite these concerns, there is no serious suggestion that the system should be abandoned or replaced with another process. Rather, the system and its implementation should be refined in a way that retains its ability to detect and reject true weeds, while increasing its capability to accept non-weeds.

The Review examines the three stages of the WRA process in turn, and makes a series of recommendations to improve each stage of the process. These recommendations are spread throughout the report, but for those readers wishing to refer to them directly, they have been brought together in Chapter 6, which contains the Review Group's Summary and Recommendations.

INTRODUCTION

The Primary Industries Standing Committee (PISC) agreed, out of session, to review the Weed Risk Assessment (WRA) System (the Pheloung System) subject to agreement of the Natural Resource Management Standing Committee (NRMSC). Members of NRMSC subsequently agreed to the review. PISC members noted concerns raised by stakeholders regarding the practical operation of the WRA System.

The agreed terms of reference for the review are:

> *"To review the operation of the Weed Risk Assessment System, with emphasis on whether the practical application and use of the system has achieved the best outcomes for Australia. Without limiting the review team in its examination, it is asked to specifically comment on:*
>
> *(a) a critical assessment of the underlying basis and philosophy behind the operation of the System itself;*
> *(b) the practical implementation and operation of the System;*
> *(c) improvements to the existing System to provide more objective and consistent outcomes for Australia.*
>
> *MEMBERSHIP*
>
> *The review team should be composed of:*
>
> *(a) two members of the Plant Industries Committee of PISC;*
> *(b) two members representing the Land Water and Biodiversity Committee of NRMSC; and.*
> *(c) additional representatives from Australian Weeds Committee, BA, Department of the Environment and Heritage, CRC Australian Weed Management Systems and CRC Plant-based Management of Dryland Salinity*
>
> *The convenor to be the representative of the Chair of LW&BC."* (Now the Natural Resource Policies and Programs Committee)

The WRA System is a science-based, quarantine risk analysis tool that was adopted by the Australian Quarantine and Inspection Service (AQIS) in 1997 as the primary method for determining the weed potential of any previously unassessed plant species proposed for importation. The system is considered to be compliant with Australia's international obligations (including the WTO and SPS agreement – see Chapter 1).

The Australian Government Department of the Environment and Heritage (DEH) was involved in the development of the WRA System and currently recognises, through their recognition of Schedule 5 of the *Quarantine Proclamation 1998*, the outcome of the assessment process in their legislation (the *Environment Protection*

and Biodiversity Conservation Act 1999). Any changes to the WRA System not meeting the legislative requirements of DEH could potentially result in DEH no longer recognising the WRA System and requiring all importers to undergo an assessment process that complies with their legislation. Other stakeholders involved in the original implementation of the WRA system include nursery and seed industry associations, state noxious weed agencies, private importers, public and private sector scientists and weed experts from around the world.

The WRA system is based on a series of questions that examine the ecology, habitat, distribution, dispersion, undesirable traits, adaptability and other attributes of the species being assessed that would contribute to the weedy potential of the species or would limit the potential of the species to become a weed.

GLOSSARY

KEY TERMS

Botanic garden There is no formal process or organization for accrediting botanical gardens in Australia. However, the term is used in this report to mean "a scientific and educational institution, the purpose of which is the advancement and dissemination of knowledge and appreciation of plants by (a) growing them in a horticultural setting; (b) establishing herbarium collections; (c) conducting research; and (d) providing displays and interpretative services", a definition which was part of the now repealed Commonwealth National Parks and Wildlife Act 1975.

Naturalised This refers to an alien plant that reproduces and sustains populations without direct human intervention. Various other definitions exist (see Richardson *et al.* Naturalization and invasion of alien plants: concepts and definitions. Diversity and Distribution 6:93-107).

Official control "The active enforcement of mandatory phytosanitary regulations and the application of mandatory phytosanitary procedures with the objective of eradication or containment of quarantine pests or the management of regulated non-quarantine pests" (IPPC ISPM #5).

Permitted Seeds List (Schedule 5 of the *Quarantine Proclamation 1998*) A list of species that are either recorded as being present in Australia and not subject to an official control program or that have been subject to the WRA process and accepted for importation.

Pheloung WRA system This is the weed risk assessment system currently used within the WRA process adopted by AQIS (now BA) in 1997. It assesses the weed potential of plant species by asking 49 questions covering the plant's domestication, climate preferences, weed history, undesirable traits, growth form and biology.

Research There is provision under quarantine legislation for importation of plant species in a quarantine secure manner for research purposes. Research in this context is work conducted by a recognized agency to directly examine a species' weed potential. There is also provision to undertake other research activities on prohibited species, provided it is done under quarantine conditions approved by AQIS.

Tier 1 This is the first stage of the WRA process where a species, proposed for importation, has no previous quarantine policy and has its quarantine status in Australia determined (that is, presence, absence and official control).

Tier 2 This is the second stage of the WRA process in which species are assessed to determine the risk potential of the species becoming a weed in Australia. This stage of the WRA process uses the Pheloung Weed Risk Assessment System.

Tier 3 This is the third stage of the WRA process in which species that have been neither accepted or rejected in Tier 2 (designated "further evaluate") can be

subjected to post-entry evaluation. A formal Tier 3 system is not currently active within the WRA process.

Weed risk assessment (system) This expression refers to any system used to assess the weed potential of a plant species. The weed risk assessment system currently used by BA is referred in this document as the Weed Risk Assessment System or Pheloung System. It is Tier 2 of BA's/AQIS's WRA process.

Weed Risk Assessment process This is the three tiered process used by BA to assess the weed potential of "new" plant species. Stage 2 of the process involves the application of the Pheloung WRA system.

Widely distributed A species is widely distributed if records indicate that it is:

(i) found naturalised in multiple, distinct locations and/or
(ii) it is readily available commercially from nurseries or seed suppliers and/or
(iii) commonly grown (e.g. as a garden, landscaping, agricultural, horticultural or forestry plant).

ACRONYMS

AQIS	Australian Quarantine and Inspection Service
BA	Biosecurity Australia
CRCAWM	Co-operative Research Centre for Australian Weed Management (Weeds CRC)
CRCPSDS	Co-operative Research Centre for Plant-based Management of Dryland Salinity
DAFF	Department of Agriculture, Fisheries and Forestry (Australian Government)
DEH	Department of the Environment and Heritage (Australian Government)
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
FAO	Food and Agriculture Organization of the United Nations
GATT	General Agreement on Tariffs and Trade
ICON	AQIS's Import Conditions Database
IPPC	International Plant Protection Convention
IRA	Import Risk Analysis
ISPM	International Standards for Phytosanitary Measures
NRMSC	Natural Resource Management Standing Committee
PISC	Primary Industries Standing Committee
R&D	research and development
SPS	Sanitary and Phytosanitary (SPS) Measures
WRA	weed risk assessment
WRAS	Weed Risk Assessment System
WTO	World Trade Organisation

CHAPTER 1 – GENERAL OVERVIEW

Introduction

Historically, many species of plants have been imported into Australia for horticultural, ornamental and/or agricultural purposes. A proportion of these species have escaped beyond the garden path, or past the farm gate, to become weeds in Australia. Species with the potential to become weeds may come from almost all types of plants grown and imported into Australia; herbs, grasses, shrubs and trees.

The cost of weeds to the environment is difficult to calculate with weeds being considered only second to land clearing as a cause of biodiversity loss. Other authors estimate that weeds cost Australian agriculture over $4 billion per year (Sinden et al 2004).

There are approximately 16,000 native plant species recorded in Australia and approximately 2,800 naturalised species of plants. It has been estimated that the rate of naturalisation over the last 100 years has been between 10 and 30 species a year (Groves 1997). Approximately 10% of the naturalised plant species are now proclaimed as noxious weeds under State/Territory legislation. Approximately 3,480 plant species have been recorded as weeds in Australia (this figure only includes exotic species) (Virtue et al 2004).

Over the 25 years (from 1971 – 1995) 65% of the plants naturalised in Australia had been imported as ornamentals, 7% for agricultural use, 6% for various reasons and only two percent as seed contamination (the remaining 26% arrived through unknown means).

In October of 2000, Mr. Michael Taylor, Secretary of the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) announced the establishment of BA, a group within DAFF to take responsibility for assessing the quarantine risks, and provide quarantine advice, associated with commodity imports, for example; Weed Risk Assessment (WRA) and Import Risk Analysis (IRA).

BA is responsible for developing quarantine advice that may form the basis for quarantine policy, in Australia, in line with Australia's international obligations and Commonwealth Government policies. It does this by assessing quarantine risks associated with imports of both plants and animals. Australia is a member of the World Trade Organisation (WTO) and BA assesses the pest risks associated with trade, using appropriate international standards. BA uses the International Plant Protection Convention[1] (IPPC) guidelines for Pest Risk Analysis (PRA) frameworks for determining quarantine pest concerns associated with imports of plant and plant products.

[1] http://www.fao.org/WAICENT/FaoInfo/Agricult/AGP/AGPP/PQ/Default.htm

International Obligations

Any measures to restrict the movement of potentially weedy plants because of the quarantine risks they pose, both into Australia and within Australia, must conform to international treaties. At the conclusion of the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) in 1994, member nations decided that specific agreements were necessary to stop countries erecting unjustified technical barriers to trade, to compensate for the proposed removal of tariffs. Australia, as a member of the Cairns group, was a strong proponent of this initiative. One of these agreements, the Agreement on the Application of Sanitary and Phytosanitary Measures (the SPS agreement), includes measures to protect human, animal or plant life or health from risks arising from quarantine pests (WTO 1994). The SPS agreement recognises the IPPC, which deals specifically with plant quarantine issues. The term "pests" is taken by the IPPC to include "weeds".

The SPS agreement came into force with the formation of the World Trade Organisation (WTO) on 1 January 1995. This agreement was motivated by a concern that unless clear rules were made in the area of sanitary and phytosanitary measures, gains achieved in the negotiations concerning agricultural trade would be eroded by the imposition of additional restrictions in the form of sanitary and phytosanitary barriers.

The SPS agreement imposes disciplines on the actions taken by national governments to regulate, amongst other commodities, the importation of plants. These actions have to be based on scientifically assessed pest risks, where these risks are considered to be significant. SPS decision processes must be transparent (that is, clearly stated and open to external scrutiny if requested). National governments are ultimately responsible for compliance with the SPS agreement and encourage its observance by 2nd tier levels of government, where measures that restrict the movement of plants within a country may affect international trade.

The agreement also requires WTO members to base SPS measures on "international standards, guidelines or recommendations". The IPPC Secretariat has been recognised by the WTO as the body responsible for coordinating phytosanitary standards development.

While measures to protect the environment are not directly referred to in the SPS agreement, they are addressed in supporting texts to the agreement. The FAO definition of a quarantine pest does not specify whether the economic impact of the pest is on agriculture, public lands or forests and so does not differentiate between weeds of agriculture or the broader environment. BA and DEH currently co-operate on new plant assessments.

The FAO (1997) defines a **pest** as (and includes weeds in the definition of pest):

"*Any species, strain or biotype of plant, animal or pathogenic agent, injurious to plants or plants products*."

and a **Quarantine pest** as:

"*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*."

The International Standards for Phytosanitary Measures (ISPM) defines "**Official Control**" as:

> *"The active enforcement of mandatory phytosanitary regulations and the application of mandatory phytosanitary procedures with the objective of eradication or containment of quarantine pests or for the management of regulated non-quarantine pests."* (FAO 2000).

Border Quarantine in Australia

Quarantine in Australia, at the international border, is primarily the responsibility of the Commonwealth Government. State and Territory governments are responsible for the development, and enforcement, of interstate quarantine.

Previously, AQIS was responsible for assessing quarantine risks. BA now performs this role. The Multilateral, Invasive Plants and Germplasm Team is the section within Plant Biosecurity responsible for the development of weed related advice provided to AQIS.

Once quarantine policies are adopted the implementation will be the responsibility of AQIS. AQIS regulates quarantine at the border and performs this task under the *Quarantine Act 1908* and subordinate legislation. AQIS is empowered to regulate the importation of all types of plant material into Australia. This Act does not differentiate between plant end usages.

BA carries out assessments for weed potential on all proposed new plant introductions, for species not already listed on AQIS's import conditions database and/or the permitted seeds list. If a species is prohibited, due to weed potential, actions taken must also be consistent with the standards and international obligations. BA considers the current assessment process is consistent with Australia's international obligations because pest risk is scientifically determined and the process is transparent.

The import of live species (including plants) is also regulated by DEH under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). In order for a species that is not on the formal list of specimens suitable for live import to be permitted for import, the potential environmental risk must be assessed. Because the WRA, as currently configured, adequately assesses the potential environmental risk of exotic plant species, DEH's live import list is taken to include any plant species the introduction of which is in accordance with the *Quarantine Act 1908*. This means that a proposed new plant import is required to undergo only one assessment process.

Review of Quarantine

Prior to 1996 Australia operated from a "prohibited list" where prohibited species were listed on a proclamation of the *Quarantine Act 1908* and any species that did not appear on the prohibited list were permitted entry. The "prohibited list" contained plant species that were either widely recognised as weeds elsewhere in the world or that had known quarantine pest and disease risks associated with them.

Quarantine in Australia was reviewed in 1996 following a number of incursions of exotic pests and diseases into Australia (Nairn et al 1996). The review team was tasked with reviewing Australia's quarantine policies and programs. This was done with regard to the health status which Australia has and the benefits and costs which flow from preserving that status, Australia's international obligations, trade impacts of Australian quarantine policies and environmental considerations. The review was to make recommendations and revisions of Australia's quarantine policy framework, revisions to the quarantine risk assessment processes, capacity of existing quarantine programs and the adequacy of the consultative processes.

The review committee recommended that the regulations governing the import of seeds and plant germplasm be based on a permitted list for entry rather than solely on the prohibited list that was in place at the time (Recommendation 54). The government provided additional funding over four years to implement this, and other, recommendations.

From July 1998, under revised legislation (the *Quarantine Proclamation 1998*), all plants were prohibited from entering Australia until they were assessed and/or appeared on the permitted list. The WRA process was adopted at this time, following an exhaustive nine-month consultation period, to assess all new proposed plant imports. The WRA process was implemented with funding from the National Heritage Trust (NHT).

Since July 1998, there has been no “prohibited list” as such. Importers wishing to bring plants or seeds into Australia must first check the import conditions database (ICON) to ascertain whether the species is categorised as permitted, and if so, what conditions apply. If the importer finds their species are permitted then plants or seeds can be imported subject to the relevant conditions. If the plants or seeds are found to have been previously assessed and rejected the importer may request a reassessment of the species if additional information has entered the public domain subsequent to the original assessment. If the plants or seeds are not permitted, and have not been assessed and/or rejected, the importer can apply for an import permit which will result in the Weed Risk Assessment process being activated.

The Weed Risk Assessment (WRA) process

The objective of the WRA process is to pre-screen material so that non-invasive plant species can be imported while preventing the importation of potentially invasive species.

The WRA is applied to all new plants proposed for introduction into Australia as tissue culture, seeds or any other propagatable material. WRA assessments are generally conducted at species level. However, on rare occasions (such as when specific varieties have different attributes from parents species) varieties may be assessed.

The WRA process is a three-tier system (Figure 1) that includes the WRA system as one of its tiers.

Tier 1

A species is subjected to the WRA process if, following its arrival at the border, there is no existing quarantine policy regarding the species.

If the species is not listed on the import conditions database (ICON)[2] and/or the permitted seeds list then tier 1 commences and the name of the species is sent to AQIS Plant Programs in Canberra for determination of the status of the species in Australia (that is, presence, absence or official control).

AQIS Plant Programs in Canberra uses a standard set of references to determine if the species is present in Australia. If the species is recorded as being present in Australia (and is not under "official control") then the species is added to Schedule 5 of the *Quarantine Proclamation 1998* provided there are no pest and disease concerns associated with the importation of the seeds of the species. Ultimately the species will also appear on the import conditions database as ‘permitted’ (along with any special quarantine requirements that may have been identified during the initial determination) and the importer is advised of the import conditions. If the species is naturalised in Australia and under "official control" then the species is added to the import condition database as ‘prohibited’.

Tier 2

If the species is not recorded in Australia as naturalised or widely distributed then the importer is asked to complete the "AQIS New Plant Introduction Forms" and submit them to allow an assessment to commence. BA receives a copy of the importer's completed plant introduction form from AQIS and commences the WRA.

The WRA is a question-based scoring system using 49 questions to determine a score related to an outcome. The WRA takes into account both weedy and non-weedy species traits. The questions are based on the domestication of the species, climate suitability, distribution of the species, weed status elsewhere in the world, undesirable traits, type of plant (for example, grass, aquatic, etc), reproductive methods, dispersal mechanisms and persistence attributes[3]. Answers are sought for questions on historical, biogeographical and biological/ecological details for each candidate. These answers are almost entirely in the form of ‘yes’, ‘no’ or ‘don’t know’, and are used to produce a score related to weediness. The score generated by the procedure is used to determine which of the three

[2] The import conditions database can be found on the AQIS homepage at http://www.aqis.gov.au/icon.
[3] A full description of the WRA system can be found at the Biosecurity Australian Internet page (http://www.affa.gov.au/plantbiosecurity).

recommendations (i.e. to reject, evaluate further or accept) will result. The question proforma is shown in Appendix 3.

Information is gathered from a wide variety of sources prior to the commencement of a formal WRA. The sources of information included primary literature, research papers, initial species descriptions, Internet and, where they exist, consultation with any appropriate experts around the world. There are three outcomes of the assessments:

- accept: the species is permitted importation if they satisfy standard quarantine requirements,
- reject: prohibit importation of the species (due to its high potential to become a weed of agriculture and/or the environment) and the species can only be imported with a permit and used under strict quarantine conditions (for example, research work); and
- further evaluate: the species is prohibited until it has been further assessed.

For those species that result in a further evaluate outcome the importer is asked to provide additional information in areas where Plant Biosecurity is unable to find information.

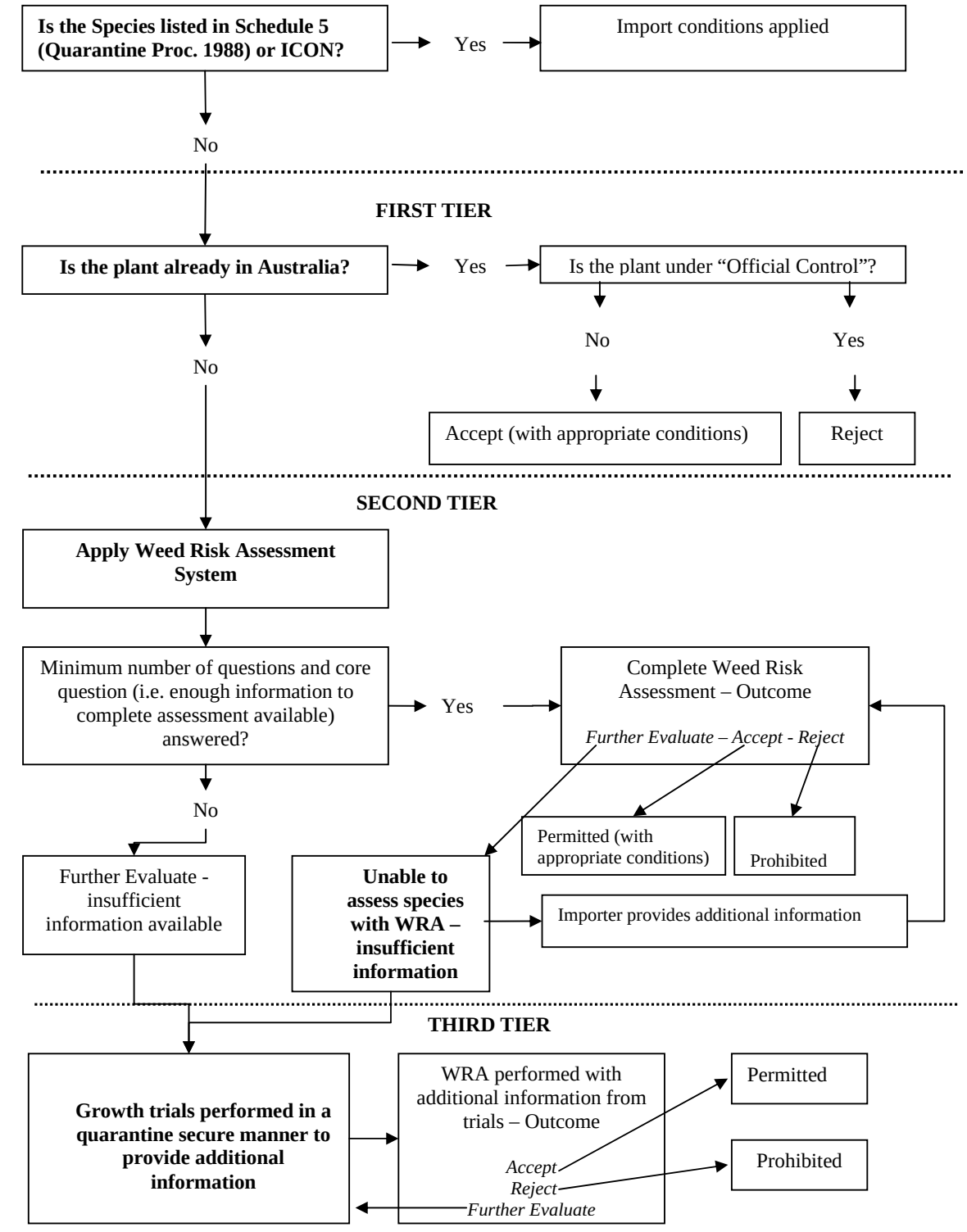


Figure 1: A diagrammatic representation of the three tiers of the Weed Risk Assessment Process.

Since the adoption of the WRA system in 1997 there have been over 2000 species assessed using the system. Over this period of time approximately 55% of the species assessed resulted in an “accept” outcome, 23% of species were rejected (that is prohibited), 20% require further evaluation and 2% of species are unable to be assessed because no information was found on the species (Figure 2).

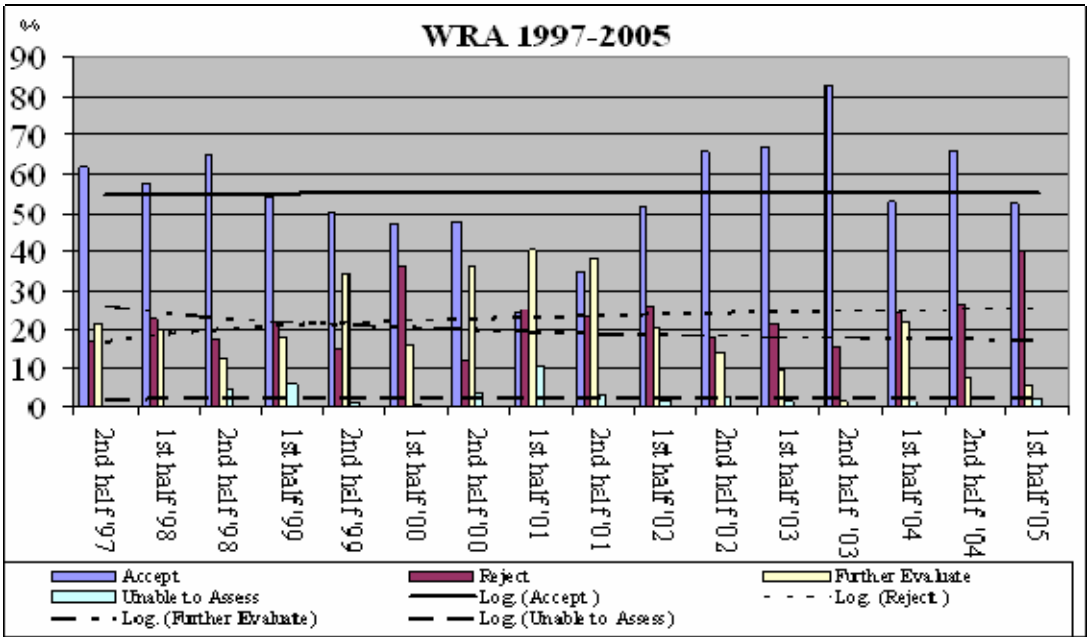


Figure 2: Trends in Weed Risk Assessments 1997-2005 (assembled from data held by Biosecurity Australia).

Tier 3

If an accept or reject recommendation cannot be determined from the Tier 2 WRAS process, and the importer wishes to proceed, there is scope for the species to be subjected to post-entry evaluation. These would be done under appropriate quarantine conditions, either in the field or in glasshouse trials to examine more directly the weed potential, so that it can ultimately be placed on ICON, the Permitted Seeds List or rejected. Procedures for Tier 3 have not yet been formalised. Currently however, utilising AQIS import permits, importers undertake information gathering exercises in Australia.

Future directions

BA has identified two areas for future directions for the assessment of new plants proposed for importation. These are the development of the third tier assessment process and an evaluation of the WRA system.

BA has identified the need to engage with appropriate stakeholders in the development of a system for gathering information to input into the WRA system whilst maintaining strict quarantine security. There is a need to identify which of

the 49 WRA questions can be answered in a quarantine secure facility while still providing the information required to complete the WRA. There will also be a requirement to identify approximate costs and the approximate time it will take to gather the information required (for example, how many generations will it take to provide appropriate results of the study). The key issue involved in the development of appropriate study methodologies will relate to the ability to maintain generic quarantine security while still providing the information required. This will be discussed in greater detail further in the report.

The Cooperative Research Centre for Australian Weed Management (Weeds CRC) has identified an evaluation of the WRA system as a part of their work plan. The examination of the WRA system was conducted in conjunction with BA. The evaluation of the WRA system involved a statistical comparison of the relationship between the questions used by the WRA system and the weightings given to each of the questions. This report is currently being finalised by the authors. Interim results are given in Box 2, Chapter 4.

Summary

The WRA system is currently one of the best systems available in the world for predicting species with the potential to be weeds of agriculture and/or the environment and is a major improvement on previous systems. The science related to the ecology and biology of plants in general, and weeds more specifically, is a developing field. Reflecting this is the evaluation of the WRA system by the Weeds CRC, applying four more years of knowledge in this emerging field. The WRA system is currently employed by several Australian States and Territories to determine the potential weediness of plants proposed for importation into their respective jurisdictions. The WRA system was adopted by New Zealand (with little change) at approximately the same time as it was adopted by Australia[4]. The USDA Forestry Service used the WRA system, on the Hawaiian Islands, to determine which species to use in reforesting degraded road sites to eliminate potentially invasive species.

Both BA and AQIS will continue to monitor developments on the world stage related to predictive tools for potentially weedy species and potential border control methods that may decrease the risk of weed species becoming established in Australia.

[4] Pheloung, Paul 2002, *Pers. Com*.

CHAPTER 2 – OVERVIEW OF ISSUES AND CONCERNS WITH THE WRAS

The WRA system has been operating since 1997 and there is now a considerable level of experience with its operations, both in the administration of the scheme and from being a client of the scheme. Most stakeholders have accepted, in principle, the need for the scheme, but issues of concern have arisen, particularly from some sectors wishing to introduce new plants species, and they include tensions between the benefits and risks of introducing new plants.

There are many different clients of the WRA process that have been identified through the seven-year operation of the system. These include wholesale nurseries, horticultural companies, agricultural suppliers, private individuals, botanic gardens, universities, CSIRO, researchers, and State and Territory governments.

Overview of Issues and Perceptions of Client Groups

1. Research and Development

Scientists involved in plant-based R&D have raised a number of concerns with the WRA system. Their main concern is that the WRA system may be preventing the introduction of new plant species into Australia which could provide substantial benefit to both agriculture and the environment. In particular, the Review Team has noted that scientists involved in major research programs such as the Cooperative Research Centre for Plant-based Management of Dryland Salinity, are concerned that new plant types will be required to solve these critical environmental issues, but the restrictions imposed by the WRA system are too risk averse to allow many of these plants to be imported.

While it is understood that scientists do not seek to introduce species with known or potential weediness, given the history of introductions in the past, they want a system which can deliver what they consider to be a more precise outcome, particularly to reduce the number of species that fall into the “further evaluate” category.

The Review Team notes that much of this criticism, particularly in relation to pasture species, may have developed as a result of the ‘bulk assessment” process which occurred as a result of a review of species held by Genetic Resource Centres (GRCs) in Australia initiated by AQIS in 1998. The review identified 800 species as priorities for assessment, resourced through the National Weeds Strategy. These assessments were outsourced by AQIS and a draft final report for 638 species was released for stakeholder comment (by BA) in 2001. The draft report raised stakeholder concerns over variation in assessment results for the same species (particularly where the same species had been assessed under different synonyms), a rate of rejection higher than the long-term average of BA and many species falling into the 'further evaluate' category (mainly due to lack of information). BA is in the process of finalising this review. Hence the quarantine

status of many species remains unresolved, with no clear decision as to whether such species can or cannot be used in ongoing plant development programs. Australian Wool Innovation Ltd (AWI) has funded a research project to undertake WRAs for a range of annual legumes in 2005 which have been held up in this process.

Observations based on the more formal assessment processes, carried out by BA, indicate that results for pasture species have not been as 'contentious' as the results from the bulk assessment trial.

Some scientists argue that consideration should be given to include an assessment of both economic and environmental benefits in the WRA system. It has been suggested that there should be a mechanism to balance the weed risk potential against the potential positive benefit, by allowing the precautionary approach to "be influenced by the potential benefit of the introduced plants", related to both economic and, more importantly, environmental benefit. However, the WTO SPS Agreement identifies the need for an assessment of economic consequences of a pest but not an assessment of the cost/benefit associated with the pest. In fact the inclusion of a cost/benefit analysis may not meet the requirements of Article 2.2 in that the assessment "... is based on scientific principles and is not maintained without sufficient scientific evidence...".

2. Environmental Issues

Department of the Environment and Heritage (DEH)
The import of live plant species into Australia is regulated by the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act) and the *Quarantine Act 1908*. The primary environmental risk associated with plant species is that they may become weeds. DEH has agreed that the WRA system as it is currently configured adequately addresses the environmental risks associated with the import of live exotic plants and that the risk assessment carried out by BA using the WRA system satisfies the requirements of the EPBC Act. This means that there is only one national assessment process for proposed new plant imports. Any amendment made to the WRA system would require DEH to re-evaluate the System to ensure that it continues to satisfy the EPBC Act.

Environment NGOs
A number of Environmental NGOs are very concerned with the threat posed to Australia's biodiversity by potentially invasive weeds. Prevention of import at the borders, along with early control of those weeds already in Australia, are seen as the most effective forms of management. In a submission to the Senate enquiry into the control of invasive species, the World Wildlife Fund for Nature (WWF) contended that "Australia needs to transform and consolidate its approach to invasive species from a reactive to a preventative approach" (WWF 2003, p.8). A preventative approach is viewed as the preferred option.

3. Commercial Sector Issues

There has been no formal consultation with commercial users of the process in this review. The potential users would mostly be the agricultural, horticultural and nursery industries. Most material introduced for these industries would be

facilitated through seed companies and the nursery industry as well as through R&D agencies. A major concern of the seed industry is dealing with contaminants of seed. However, the issue of contaminants is outside the scope of the WRA system and of this review.

Businesses which deal with sale and distribution of plants have a potentially significant interest in the operation of the WRA system. It is arguable however, that where new plant types are being imported purely for amenity, landscaping or ornamental features, then there is much less public good value in modifying the system. Nevertheless, any revision to the system which does not actually increase the level of risk of introducing new weeds would presumably be supported by the commercial sector.

Specific Technical Operation and Generic Technical Issues

Some specific concerns which have been raised by client groups, mainly by the scientists, include:

Tier 1

- Nomenclature and use of synonyms are major issues of concern.
- A Prohibited List should also be formally adopted to avoid the need for importers to undertake an assessment if this has already been done on particular species. (NB The Review Team has noted that this is not desirable or necessary. A formal Prohibited List may lead importers to conclude that if a species is not on the Prohibited List then it must be 'approved'. It is for this reason that the emphasis is now to only recognise a Permitted Seeds List. Importers can however check AQIS's ICON database which lists the status of all species which have been assessed and currently categorises all prohibited species as Quarantine Species. Importers should therefore be encouraged to check ICON first to determine if a species has already been assessed. This is also important for species that are permitted, as permitted species may require special import conditions.)

Tier 2

- Weediness scores. The WRA system places plants into three categories; "permitted', "prohibited" or "further evaluate". If the system cannot clearly differentiate between a weed and non-weed, the precautionary approach is adopted and the potential introduction of the species can be further evaluated. However, if the precision of the scoring system could be improved, this could reduce the proportion of plants falling in the "further evaluate" category. Some stakeholders consider that this outcome may be achieved by addressing the following issues:
    - Some questions in the scoring sheet may not be appropriate or may need modifying or clarifying.
    - The impact of non-responses to questions may need to be overcome.
    - The relative weighting of questions may need to be reassessed.
    - A filter system could be considered, rather than relying on a single score. A single, total score, tends to put all issues in the "one basket",

even though different weightings are put on different categories. A filter process might allow a plant to be ruled out if it had certain non-negotiable characters (e.g. weed elsewhere in areas with similar climates) while allowing some extra level of discretion for less threatening characteristics which could more readily be "further evaluated", especially under specified controlled field studies.

- Species related to existing introductions. Where the potential impacts of proposed introductions are functionally no different to already widely dispersed species with little relative impacts, some stakeholders consider that this should be taken into account in assessing introductions which closely resemble species already widely distributed, for example, species of the genus *Trifolium*.
- Inconsistency of the assessment process. There is a perceived need for improved quality control in the assessment process to minimise inconsistencies in scoring, confusion over nomenclature and evaluator variation.

Tier 3

- Lack of clear guidelines for the Tier 3, 'further evaluate' process. It is argued by some stakeholders that for many species entering the evaluation system there will be insufficient information to undertake a realistic analysis. For these species there is a need to provide clear guidelines for processes that would allow further information gathering while minimising the risk of weed escape.
- This is an area which should be further developed. Clients of the system could propose an assessment process which could be assessed by BA and AQIS for any quarantine risks.

Resources

While resource issues are not a direct element in the design effectiveness of the WRA system, they do potentially impact on the accuracy, operational effectiveness and efficiency of the process.

The assessments require significant staff and resources to implement, and require specific high level skills. However, the policy is not to charge for assessments as a charge may encourage clients to avoid the system. Reducing the risk of avoidance and unlawful importation of material is critical.

As one of the issues raised relates to consistency of assessments and quality management of the system, then adequate resources must be made available to ensure that problems are not accentuated by inadequate resourcing.

Resources are also needed by clients of the system if they choose to further evaluate their material. This issue is related to the need identified by clients for clearer guidelines for Tier 3 evaluations.

Specific resourcing issues and needs:

1. To ensure adequate resources are allocated for the assessment process, to get highly skilled assessors, to improve quality, consistency and timeliness of assessments.
2. To provide guidelines for the WRA Tier 3 processes.

Balancing Economic Advantage with Protecting the Environment

Protection of the environment must not be compromised through any relaxation of the system which would allow serious new weedy species to enter Australia. The real issue is to ensure that potentially useful plants are not unnecessarily prohibited through measures which are not scientifically justified.

The results of assessments of the system indicate that it is very successful in rejecting most weedy species, particularly serious weeds. This level of effectiveness must be maintained.

It has also been argued that the system should incorporate some form of benefit:cost analysis, or to at least take into consideration the potential usefulness of a plant, to provide a more balanced approach. However, even if this argument might have merit, under WTO rules only scientific criteria can be used to determine quarantine criteria. Economic benefits cannot be considered.

It is noted that a University of New England PhD student is undertaking a project on benefit:cost of plant imports for salinity mitigation, and the results of this project may be useful for further consideration of this issue.

Conclusions

While some stakeholders are critical of aspects of the WRA system, there is no serious suggestion that the system should be abandoned or replaced with another process. It is generally agreed that the current system has demonstrated that it is robust and effective. The main issues raised by stakeholders relate to:

- Concerns regarding prevention of introduction of ‘non weedy’ new plant material which could provide substantial benefits to agriculture and the environment,
- The need for the system to deliver consistent and transparent results.
- The need for the system to comply with the requirements of the EPBC Act.
- Continued need to prevent entry of potentially invasive species which affect the environment.
- Continued need to meet the needs of the commercial sector.

Some plant importers believe that the WRA system may be too risk averse and also may deliver some inconsistent results. The Review team believes that this may have partly arisen due to the ‘bulk assessment trial’ which was not successful. Many of the concerns could also be addressed by making the process more transparent.

The Review Team has identified a lack of knowledge and awareness on the part of industry of the WRA system and the processes to follow in complying with the system as a further issue to address.

The Review Team has considered these issues and has agreed that, overall, the WRA system is meeting its objectives to reject weeds, but in doing so it may also be rejecting non-weedy plants. There is a strong case to refine the system and its implementation to retain its ability to detect and reject true weeds, while increasing its capability to accept non-weeds. Any modifications must still be constrained by biological and ecological criteria and statutory requirements.

Solutions should seek to:

- improve the assessment to reduce the number of weeds that fall into the "further evaluate category",
- overcome inconsistencies in nomenclature and use of synonyms,
- increase transparency to improve consistency of the assessments,
- provide greater clarity and access to information on the import status of species (i.e. permitted, prohibited or unassessed),
- modify the Tier 2 WRA system for greater precision,
- develop clear guidelines for Tier 3 assessment,
- provide adequate resources to ensure greater precision, transparency and confidence in the system, and
- improve communication to, and understanding by, the commercial sector and the community.

These and other specific issues are dealt with in more detail in the following Chapters.

CHAPTER 3 - TIER 1 OF THE ASSESSMENT PROCESS

Tier 1 of a plant assessment contains two critical phases, the identification followed by the decision process phase. The most significant step is to determine the correct identity of the proposed import.

Phase One: Identification
Taxonomy
Before a proposed plant import can be assessed, the plant must be identified. Several problems can arise in this area and most are due to the importer not being familiar with the Latin binomial nomenclature system used to name all life forms.

Common problems that can be met in this phase

- Species name unknown: (normal when dealing with hybrids or cultivars of long standing, or when the importer does not understand the difference between a cultivar and a species)
- Name provided is wrong (i.e. species not known to be in trade anywhere and the importer claims it is commonly traded, or description data and information provided by importer does not match that for the name provided)
- Other common issues with nomenclature include:
  - Name is invalid or illegal (i.e. a synonym)
  - Name cannot be verified (ie name has not been validly published)
  - Name has only just been published (information on these species is usually limited).

Determination of accepted name
In determining, or confirming, the currently accepted name many sources of information need to be consulted. These include any recent monographs on the appropriate Family or genus in question, online databases of either herbaria or germplasm collections, texts in libraries and classic literature searches.

There are several major databases which have proven very useful over the years in determining the accepted names of plants and these include:

- Tropicos 3 the Missouri Botanic Gardens collections database http://mobot.mobot.org/W3T/Search/vast.html
- G.R.I.N. The US Agricultural Research Services Germplasm Research Index Network. www.ars-grin.gov/npgs/tax/taxgenform.html
- I.P.N.I. The International Plant Name Index, www.ipni.org/
- A.P.N.I. The Australian Plant Name Index www.anbg.gov.au/cgi-bin/apni
- ILDIS The International Legume Database Information Service, www.ildis.org/LegumeWeb/
- ING The Index Nominum Genericorum, very useful in determining the validity of obscure genera names. http://rathbun.si.edu/botany/ing/
- The Flora Europaea, covers the European flora and clearly indicates accepted and synonymous names. http://193.62.154.38/FE/fe.html
- USDA Plants Database, covers the US flora and clearly indicates accepted and synonymous names. http://plants.usda.gov/

It is also expected that the plant assessor will have developed a significant repository of plant data holding much useful information. For example, the Western Australian Department of Agriculture has a database containing over 500,000 plant names with over 1.26 million referenced records for these names including synonyms and accepted names.

Working from the original information, and if needed subsequent information provided by the importer, the correct species name should be arrived at before any further work is attempted. Any extra information supplied by the importer is validated before it is used in the assessment process. It is rare for importers to provide referenced information but this does help speed the assessment process significantly.

"Name shopping"

"Name shopping" is the intentional misnaming of a plant using a name known to be on the permitted seeds list for what is in reality an unassessed or quarantine species. This is the simplest way of importing seed material without actually smuggling the seed in. This practice is difficult to detect as many seed in the same genus look similar and quite often are identical. Experienced inspectors are often the only means of detecting this problem, usually becoming suspicious of importers when they start changing the supplied names of imports when told they need assessment or are quarantine species.

The practice of “Name shopping” may result in material that should undergo a WRA, not in fact doing so. The possibility that this could happen concerned the Review Group, and it was agreed that this should be brought to the attention of AQIS, and referred to the Steering Group which is preparing the framework for the agricultural and environmental elements of the National Biosecurity Strategy (which includes addressing Invasive Species issues).

Recommendation

• That AQIS and the Steering Group on BIOSEC be advised of the Review Group’s concerns that the practice of “Name shopping” may result in material that should undergo a WRA, not in fact doing so.

Case Study - Why determining the correct ID is critical to any assessment system.

Incorrect *Lupinus* sp. ID

A sample of lupin seed was recently imported into Australia by one of the germplasm collections labelled as *Lupinus ornatus*. As the seed is in the genus *Lupinus* only seed grown in post entry quarantine is allowed to be released within Australia and this seed was subsequently processed then distributed under this name. Unfortunately the correct name is *Lupinus sericeus* Pursh. and considering the large number of synonyms and subspecific taxa attributed to this species it is probably not the first time this plant has been mis-identified by collectors.

Synonyms: *Lupinus aegra-ovium* C.P. Sm., *Lupinus aliumbellatus* C.P. Sm., *Lupinus amniculi-salicis* C.P. Sm., *Lupinus blankinshipii* Heller, *Lupinus buckinghamii* C.P. Sm., *Lupinus falsocomatus* C.P. Sm., *Lupinus fikeranus* C.P. Sm., *Lupinus flavicaulis* Rydb., *Lupinus flexuosus* Lindl. ex J. Agardh, *Lupinus herman-workii* C.P. Sm., *Lupinus huffmanii* C.P. Sm., *Lupinus huilcoflorus* C.P. Sm., *Lupinus jonesii* Blank., non Rydb., *Lupinus larsonanus* C.P. Sm., *Lupinus leucopsis* J.G. Agardh, *Lupinus marianus* Rydb., *Lupinus ornatus* Douglas, *Lupinus puroviridus* C.P. Sm., *Lupinus quercus-jugi* C.P. Sm., *Lupinus ramosus* A. Nels., *Lupinus rickeri* C.P. Sm., *Lupinus spiraeaphilus* C.P. Sm., *Lupinus subulatus* Rydb., *Lupinus tuckerianus* C.P. Sm.

Despite this easily sorted taxonomic discrepancy, that should have been determined prior to the entry of this seed into Australia, it was distributed under the wrong name. It may well have ended up in numerous trials if not for the intervention by WAQIS officers who picked it up because the name supplied was not on that State's Permitted list. Weed Risk Assessment was relatively simple, the species is highly toxic to sheep and goats, and it causes birth deformities in cattle if ingested during the right period of gestation. Because of this toxicity and its relatively low palatability, it also dominates pastures in its native range and has to be managed with herbicides to prevent it creating a toxic monoculture. The problematic alkaloids are also persistent, meaning any hay or fodder produced with enough of this species in it is also toxic.

These features easily pushed the species through the assessment process scoring a 9 (Reject) and *Lupinus sericeus* is now a quarantine weed for Western Australia.

This highlights a significant quarantine concern that was addressed by the Senate Inquiry into Invasive Species. Under current AQIS entry conditions many thousands of plant genera are permitted entry to Australia with virtually no checks on the species within these genera. An effective screening system would never have allowed this particular species into Australia, except under strict germplasm collection conditions for dispersal to other countries collections with notes to any future users on its potential weediness. WWF Australia has made a submission to the senate enquiry on this problem including a detailed report by Spafford-Jacob *et al.* (2004). BA is currently undertaking a review of the Permitted genera on the permitted seeds list with the aim of removing all genera listings by the end of 2006.

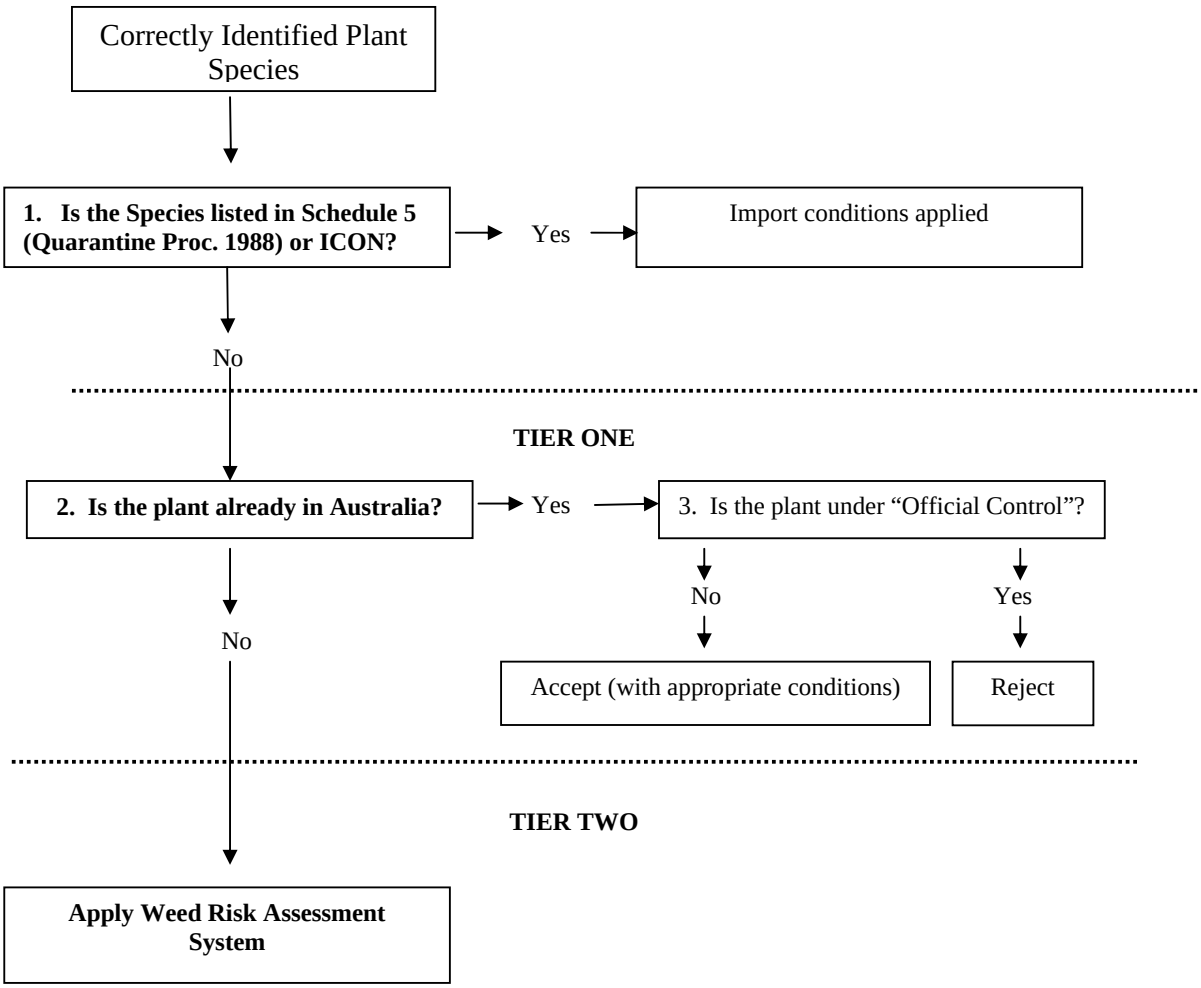
References

Spafford-Jacob, H., Randall, R.P. and Lloyd, S.G. (2004) *Front Door Wide Open to Weeds: An examination of the weed species permitted for import without risk assessment*. WWF Australia. (140 pp.)

Phase Two: Decision by Status
This phase follows the simple flow chart below and contains three decisions:

1. Are there existing quarantine procedures?
2. Is the species present in Australia?
3. Is the species under Official Control?

The background to each of these steps is considered in more detail below.



1. Are there existing quarantine procedures?
If the species is not recorded on ICON and/or the permitted seeds list then an assessment is required. If a species is on ICON it can either be permitted under any number of conditions depending on the form in which the introduction is taking place ie, cuttings, seed, bulbs etc; or prohibited, in which case the species is on ICON as a quarantine weed which effectively prohibits the introduction of this plant.

As discussed in Chapter 2 there is no formal prohibited list of plant species. Instead the emphasis is on a permitted list so that importers can clearly gauge what species are allowed. However, this species list is not readily accessible as a

web document from the AQIS or BA website. Rather individual species need to be searched on ICON. The ICON permitted seeds list is based on the most up-to-date amended legislation (Schedule 5 of the *Quarantine Proclamation 1998*). This is available from the Commonwealth Government Attorney Generals Department "Comlaw" web page, the address being as follows: (http://www.comlaw.gov.au/ComLaw/Legislation/LegislativeInstrumentCompilation1.nsf/all/search/991B2B95856B85D9CA2570BC00121D44?OpenDocument). For plant importers, however, it would be useful to be able to readily access a summary document on permitted seeds via a direct link from the AQIS web site.

Many genera have been exempt from import conditions, aside from some specific species that are listed as quarantine weeds (Spafford-Jacob *et al*. 2003). This specific issue is now in the process of being rectified, with a Ministerial commitment to have no exempt genera on the permitted seeds list by the end of 2006.

The Review Group notes and welcomes the review of the Permitted seeds List currently being undertaken by BA.

Recommendation

That a link to the permitted seeds list, as contained in the relevant quarantine legislation, be provided on the AQIS website.

2. Is the species present in Australia?

There are a number of questions to consider in this step:

- Is the species regularly imported?
- Is it native or naturalised here?
- Is it available from nurseries or other plant sources?

Species that are common in trade, and this trade can be substantiated, would be added to the Permitted Seeds List without further consideration unless it is under official control or has quarantine pest and disease concerns associated with the movement of seed germplasm. The same applies for any native species that may be imported and naturalised species that do not fall under the category of "Official Control".

Certainly any species, not on ICON, that has no history of trade in Australia and is not known to be present here at all will require an assessment.

There is some contention over the quarantine status of material held in Genetic Resource Centres (GRC), Botanic Gardens and field research trials that have not been assessed for weed risk and which are not available commercially and/or naturalised.

Under Australia's Constitution AQIS/BA has no management jurisdiction for the vast majority of germplasm held in such organisations, unless they are maintained in an AQIS Quarantine Approved Premises or species are subject to AQIS permits. It could be argued that such species are of limited distribution and that, if demonstrated to pose a weed risk, preventative action to prohibit their further propagation is the most cost-effective management action. However, this is a Constitutional role for States and Territories.

The Western Australian Department of Agriculture is currently undertaking a department wide audit of all plant material to determine just what is being held in its numerous collections. Royal Botanic Gardens Melbourne is also reviewing its collection with the aim of removing all potential weeds and has hosted a national workshop on WRA requirements for botanic gardens in August 2005.

There is currently no nationwide audit/tracking system for unassessed material held by Botanic gardens, GRCs and other research organisations. Such an audit could potentially be of great benefit to know the status of the nation's germplasm and plant collections and indicate any weed risks within.

The issues raised above on monitoring for and assessing the weed risk of new plant species within Australia's border need to be considered by the current national biosecurity planning process.

Recommendation.

That the issues relating to monitoring for and assessing the weed risk of new plant species within Australia's border, particularly material held by Botanic gardens, GRCs and other research organisations, need to be considered by the current national biosecurity planning process.

3. Is the species under "Official Control"?
According to the IPPC ISPM 5 *Glossary of Phytosanitary Terms*, (Supplement N°.1) the definition of "Official Control" is

The active enforcement of mandatory phytosanitary regulations and the application of mandatory phytosanitary procedures with the objective of eradication or containment of quarantine pests or for the management of regulated non-quarantine pests.

Because "Official Control" is a status applied, regulated and monitored by the States and Territories it is important that this information is easily available to the assessor for them to accurately determine if a proposed import is currently under "Official control" anywhere in Australia. The *Weeds Australia* web site is currently the best overall source of this information. <www.weeds.org.au/index.html>

"Official control" includes:

- Eradication and/or containment of the infested area/s
- Surveillance in the endangered area/s
- Measures related to controls on the movement into and within the protected area/s including any measures applied during importation.

Two examples of "Official control" include the aquatic weed salvinia (*Salvinia molesta*) which is a noxious weed/declared plant in all States and Territories and nodding thistle (*Carduus nutans*) which is a noxious weed/declared plant in Victoria, New South Wales, Tasmania and Western Australia but isn't regulated in the other States or Territories. Both species are listed as quarantine weeds on ICON because of the official control enforced by the various jurisdictions.

By comparison wild oats (*Avena fatua*) is a major crop weed, found throughout the country, but it is not a regulated weed anywhere. Hence it is not considered a quarantine pest although there are a set of post-entry quarantine conditions listed on ICON to prevent other pests and pathogens using this pathway.

Another requirement of "Official control" is that these procedures are mandatory under law and are monitored and enforced by government/s or an appropriate legislative authority.

SKILLS

The Proponent

The proponent of any plant importation needs no specific skills or attributes but it certainly helps their attempts to import a plant if they have a good understanding of the plant's true identity. Most efforts at importing plants stall at this point for obvious reasons. Any other information the proponent can supply to the assessor in terms of referenced and documented data on the plant's biology assists both the assessor and the proponent. AQIS requires all proponents of a plant importation that has not been assessed to fill in a Plant Introduction form (see Appendix 1). If this form is completed effectively the assessor's job is much easier.

The Assessor

The job of assessing plants for their weed potential is not easy and should never be attempted by a novice without the supervision of an experienced assessor.

Determination of the correct identification is the first difficult step as many people find the intricacies of botanical nomenclature and its many and various rules very confusing. A good understanding of this area is critical for any assessor to work effectively.
Access to libraries, literature search facilities, the internet and databases is essential. A ready reference library of useful sources close to hand helps a great deal.

A background in plant or general biology and/or ecology is also a valuable asset. A background in the weed science discipline is valuable to further develop an assessor's understanding of what makes a plant weedy and what does not. Simple interpretation of a plant's biological and physical characteristics, taken out of context with its native environment, does not allow for a complete understanding of a plant's weed potential. Climate, soil type, breeding systems, pollinators and associated species all need to be considered and can often be the only way to identify potential weeds from species with no previous history as a weed.

Recommendation.

• BA should ensure their assessors have adequate access to the training, materials and resources required for weed risk assessment.

Summary of Recommendations

1. That AQIS and the Steering Group on BIOSEC be advised of the Review Group's concerns that the practice of "Name shopping" may result in material that should undergo a WRA, not in fact doing so.

2. That a link to the permitted seeds list, as contained in the relevant quarantine legislation, be provided on the AQIS website.
3. That the issues relating to monitoring for and assessing the weed risk of new plant species within Australia's border, particularly material held by Botanic gardens, GRCs and other research organisations, need to be considered by the current national biosecurity planning process.

4. That BA ensure their assessors have adequate access to the training, materials and resources required for weed risk assessment.

CHAPTER 4 - TIER 2 OF THE ASSESSMENT PROCESS

Introduction

Tier 2 is the use of the Pheloung WRA system to predict the potential weediness of a new plant species introduction to Australia. This chapter evaluates the Pheloung WRA scoring system with regard to the three terms of reference of the review (see introduction). The WRA system's development is described and its performance examined via a literature review of various scientific studies. Potential areas for improvement to increase the system's predictive accuracy are then suggested. This chapter is focused on the WRA system as a scientific tool and hence it is written from a technical perspective.

Development of The Pheloung System

Basic structure

The Pheloung WRA system (Pheloung 1995(ie Appendix 2); Pheloung 2001) consists of 49 questions covering the plant's domestication, climate preferences, weed history, undesirable traits, growth form, reproduction, dispersal and persistence attributes. These questions were selected after a national workshop of weed scientists (Panetta *et al.* 1994).

The WRA system is an additive model, and questions are mostly answered as 'yes', 'no' or 'don't know' with a '+1' score for a weedy attribute and a '–1' score for a non-weedy attribute. Hence a species is predicted to be a weed if it accumulates a certain number of risk factors. A minimum number of questions from each of three main sections (Biogeography, Undesirable attributes and Biology/ecology) must be answered to generate a score. The total score determines whether a plant is accepted for import (score of <1), rejected for import (score of >6) or requires further evaluation (score of 1 to 6). Figure 3 shows an example scoresheet for Siam weed using the WRA system. The WRA system also partitions the outcomes into an environmental and agricultural weed score which is derived from relevant answered questions and is provided as part of the assessment outcome scores.

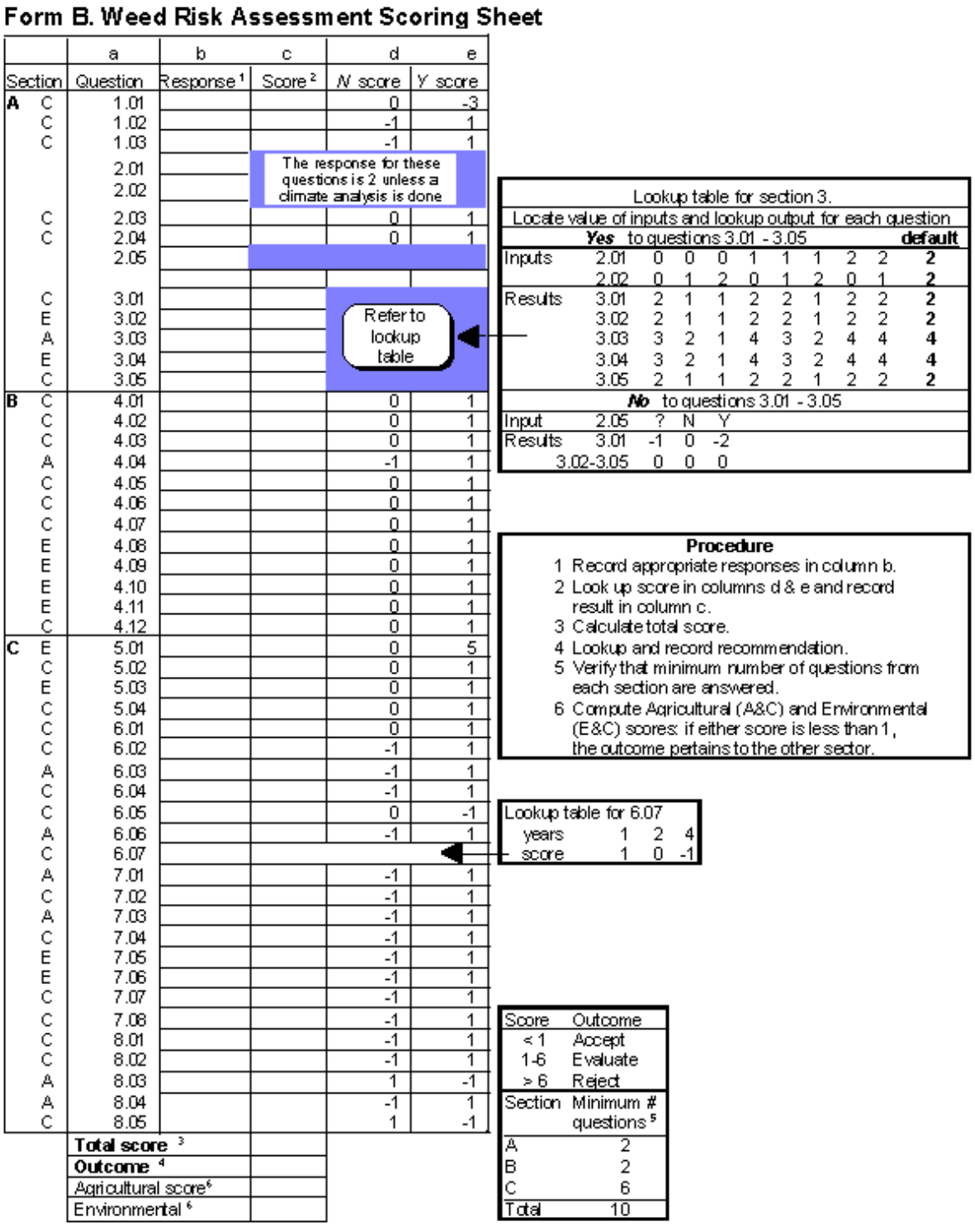
Weightings were generally avoided as there was considered to be an insufficient scientific basis for ranking the relative importance of questions (Pheloung 1995). However, some weightings (i.e. scores greater than +1) were included for five questions on weed status outside Australia (questions 3.01-3.05) when a high climate match was obtained and aquatic species (question 5.01) also got a higher score (Figure 4). These were deemed necessary to maximise the discriminatory performance of the system.

Figure 3. Example scoresheet for Siam weed in the WRA system (from Pheloung 2001).

		Botanical name:		*Chromolaena odorata*	Outcome: Accept <1 Evaluate 1-6 Reject >6	Reject
		Common name:		Siam weed	Score:	23
		Family name		**Asteraceae**	Your name:	CW
				History/Biogeography		
A	**1**	*Domestication/*	1.01	Is the species highly domesticated? If answer is 'no' go to question 2.01		N
C		*cultivation*	1.02	Has the species become naturalised where grown?		
C			1.03	Does the species have weedy races?		
	2	*Climate and*	2.01	Species suited to Australian climates? (0-low; 1-intermediate; 2-high)		2
		Distribution	2.02	Quality of climate match data? (0-low; 1-intermediate; 2-high)		2
C			2.03	Broad climate suitability (environmental versatility)?		N
C			2.04	Native or naturalised in regions with extended dry periods?		Y
			2.05	Does the species have a history of repeated introductions outside its natural range?		Y
C	**3**	*Weed*	3.01	Naturalised beyond native range?		Y
E		*elsewhere*	3.02	Garden/amenity/disturbance weed?		
A			3.03	Weed of agriculture/horticulture/forestry?		Y
E			3.04	Environmental weed?		Y
			3.05	Congeneric weed?		Y
				Biology/Ecology		
A	**4**	*Undesirable*	4.01	Produces spines, thorns or burrs?		N
C		*traits*	4.02	Allelopathic?		N
C			4.03	Parasitic?		
A			4.04	Unpalatable to grazing animals?		N
C			4.05	Toxic to animals?		Y
C			4.06	Host for recognised pests and pathogens?		
C			4.07	Causes allergies or is otherwise toxic to humans?		
E			4.08	Creates a fire hazard in natural ecosystems?		Y
E			4.09	Is a shade tolerant plant at some stage of its life cycle?		N
E			4.10	Grows on infertile soils?		N
E			4.11	Climbing or smothering growth habit?		Y
E			4.12	Forms dense thickets?		N
E	**5**	*Plant type*	5.01	Aquatic?		N
C			5.02	Grass?		
E			5.03	Nitrogen fixing woody plant?		
C			5.04	Geophyte?		
C	**6**	*Reproduction*	6.01	Evidence of substantial reproductive failure in native habitat?		N
C			6.02	Produces viable seed?		Y
C			6.03	Hybridises naturally?		
C			6.04	Self-fertilisation?		
C			6.05	Requires specialist pollinators?		N
C			6.06	Reproduction by vegetative propagation?		Y
C			6.07	Minimum generative time (years)?		1
A	**7**	*Dispersal*	7.01	Propagules likely to be dispersed unintentionally?		Y
C		*mechanisms*	7.02	Propagules dispersed intentionally by people?		
A			7.03	Propagules likely to disperse as a produce contaminant?		Y
C			7.04	Propagules adapted to wind dispersal?		Y
E			7.05	Propagules buoyant?		Y
E			7.06	Propagules bird dispersed?		
C			7.07	Propagules dispersed by other animals (externally)?		Y
C			7.08	Propagules dispersed by other animals (internally)?		
C	**8**	*Persistence*	8.01	Prolific seed production?		Y
A		*attributes*	8.02	Evidence that a persistent propagule bank is formed (>1 yr.)?		
A			8.03	Well controlled by herbicides?		Y
C			8.04	Tolerates or benefits from mutilation, cultivation or fire?		
E			8.05	Effective natural enemies present in Australia?		

Weed type characteristic A= agricultural, E = environmental, C= combined

Figure 4. Weed Risk Assessment System scoring sheet



Form B. Weed Risk Assessment Scoring Sheet

		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 for these questions is 2 unless a climate analysis is done		
		2.02				
	C	2.03			0	1
	C	2.04			0	1
		2.05				
	C	3.01		Refer to lookup table		
	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				
	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 [6]				
		Environmental [6]				

Lookup table for section 3.										
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	3	2	1	4	3	2	4	4	**4**
	3.04	3	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						

Procedure

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

Lookup table for 6.07			
years	1	2	4
score	1	0	-1

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

Section	Minimum # questions [5]
A	2
B	2
C	6
Total	10

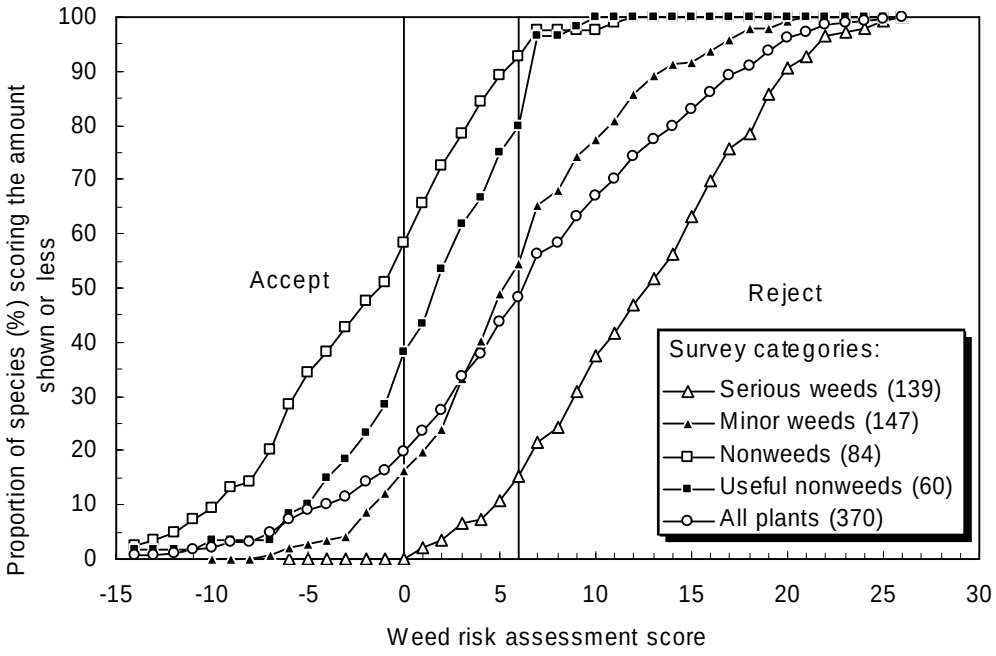
Initial development and testing

The WRA system was developed from a test data set of 370 plant species, contributed by six expert groups across Australia (Pheloung 1995). Assessors were asked to treat each species as if it had not yet arrived in Australia. Separate to this was a ranking of species on a scale of 0-2 for weediness and usefulness by 11 expert groups across Australia. Analysis of the rankings gave a test data set of 139 serious weeds, 147 minor weeds and 84 non-weeds (Pheloung 1995).

Plotting the cumulative frequency distributions of weed risk assessment score for the non-weeds, minor weeds and serious weeds (Figure 5) led to selection of the critical values for acceptance and rejection. A score of less than one for 'accept' meant that no serious weeds were accepted and 16% of minor weeds were accepted. A score of greater than six meant that less than 7% of non-weeds were rejected. 29% of species fell into the 'further evaluate' category, scoring in the range 1-6 (Pheloung 1995).

Pheloung (1995, 2001) compared his system to two predecessors; Hazard (1988) and Panetta (1993). Whilst these latter two systems were simpler (having fewer questions than the Pheloung system) they had poorer performance in terms of producing too many ‘evaluate’ recommendations or rejecting too many non-weeds.

Figure 5 Cumulative frequency of species receiving a given WRA score or less (from Pheloung 2001).



Implementation within AQIS

Minor changes were made to the wording of some questions when AQIS adopted the Pheloung WRA system in 1997 (Walton 2001) to improve their understanding by assessors. The AQIS Plant Introduction Form (see Appendix 1 and Chapter 3) was developed for importers of plant material. The current format of the questions in the WRA system is in Appendix 3.

The Performance Of The Pheloung WRA System

Accuracy of the System

Use of the Pheloung WRA system (and many other pest screening systems) is a compromise between maximising the proportion of true weeds predicted (i.e. the test's sensitivity) and the proportion of true non-weeds predicted (i.e. the test's specificity). Further information on methods to evaluate weed screening systems are given in Box 1. Table 1 summarises results from various studies on the accuracy of the Pheloung WRA system (Box 2).

Table 1 Tests of sensitivity (% true weeds predicted) and specificity (% true non-weeds *predicted) of the Pheloung system.*

Study	Sensitivity	Specificity
Smith *et al*. 1999	70%	53%
Pheloung *et al*. 1999[1]	83%	70%
Daehler and Carino 2000	93%	54%
Daehler *et al*. 2004	88%	66%
Jefferson *et al*. 2004	100%	0%[2]

[1] Considered 'further evaluate' to be minor weeds

[2] 45% non-invaders scored 'reject' and 55% 'further evaluate'

The system does well for sensitivity at *ca.* 87% but specificity of *ca.* 60% (ignoring Jefferson *et al*. 2004) is low. Use of the system constitutes a precautionary approach, but not necessarily an inappropriate approach. The prevailing community attitude may be that there are more than enough weeds in Australia already, causing a substantial ongoing cost of at least $4 billion per year (Sinden *et al*. 2004). The majority of plant introductions do not provide a major benefit anyhow (e.g., only 5% of pasture introductions to northern Australia were deemed useful – Lonsdale 1994) and their predicted utility may be as difficult to judge at the border as predicted weediness (Bennett and Virtue 2004). However, the difference in performance between sensitivity and specificity is exacerbated by the 'base rate effect' (Smith *et al*. 1999). For weeds this is the proportion of plant introductions that actually become weeds. A base rate of 2% led to an estimate of a 1 in 10 chance of a predicted weed being a real weed (Smith *et al*. 1999, Hughes and Madden 2003). However, this may be unduly pessimistic as Virtue *et al*. 2004 estimated the base rate for weeds in Australia as 7% (exotic species recorded as agricultural, noxious and/or natural ecosystem weeds). Nonetheless we should be aiming to increase specificity of the Pheloung WRA system whilst maintaining a high level of sensitivity.

The cut-off scores which distinguish 'further evaluate' from 'accept' and 'reject' are problematic. Whilst it has been shown that a score of 6 is robust for rejecting true weeds (Pheloung *et al*. 1999; Caley *et al*. 2005) and a score of 0 is appropriate for not accepting serious weeds (Pheloung 1995), there remains considerable uncertainty over the true status of 'further evaluate' species. Pheloung *et al*. (1999) categorised them as minor weeds in their analysis, but Caley *et al*. (2005) showed that the probability of weediness is very low and highly variable in the 'further

evaluate' range of scores. Changes to the system that would result in a reduction in the proportion of cases falling into the 'further evaluate' range, with a corresponding increase in 'accept' or 'reject' outcomes, would be a desirable improvement.

BOX 1 Evaluating the technical performance of weed screening systems

A predictive weed screening system has four possible outcomes (Lonsdale and Smith 2001):

1. true positives (TP), where actual weeds are predicted to be weeds by the system;
2. true negatives (TN), where actual non-weeds are predicted to be non-weeds;
3. false negatives (FN), where actual weeds are predicted to be non-weeds; and
4. false positives (FP), where actual non-weeds are predicted to be weeds.

There are two key measures of the performance of pest screening systems; 'sensitivity' and 'specificity' (Lonsdale and Smith 2001, Hughes and Madden 2003).

Sensitivity is the probability of correctly rejecting a weed (i.e. the true positive proportion, (TPP)):

$$TPP = TP / (TP + FN) \quad [= (\text{true weeds predicted}) / (\text{total actual weeds})]$$

Specificity is the probability of correctly accepting a non-weed (i.e. the true negative proportion, (TNP)):

$$TNP = TN / (TN + FP) \quad [= (\text{true non-weeds predicted}) / (\text{total actual non-weeds})]$$

Combining these two equations gives a measure of 'overall accuracy' (i.e. a combined measure of the proportion of weeds and non-weeds correctly identified):

Overall Accuracy $= (TP + TN) / (TP + TN + FN + FP)$

$[= (\text{total true predictions}) / (\text{total species tested})]$

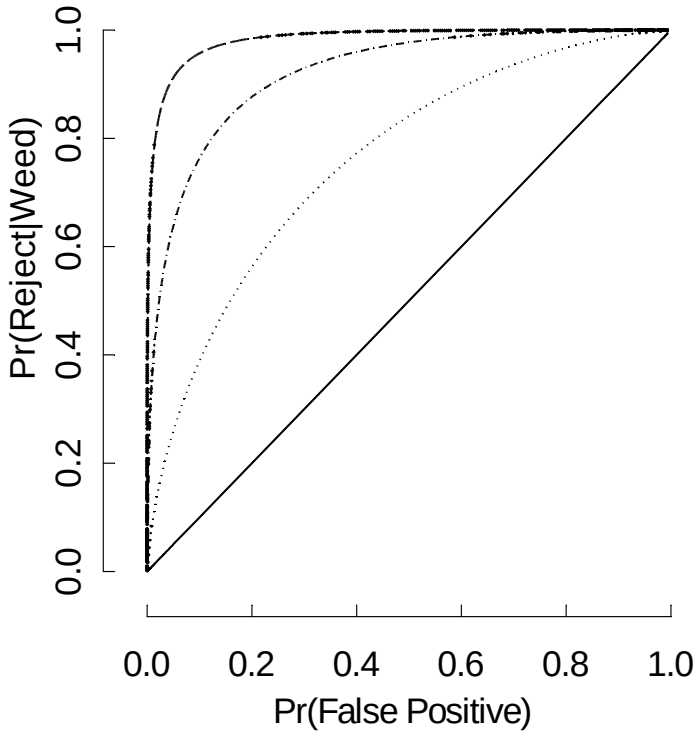
$[= (TPP \times \text{proportion of actual weeds}) + (TNP \times \text{proportion of actual non-weeds})]$

However, overall accuracy figures can be misleading, as these depend on the initial proportions of weeds and non-weeds in the data set (Smith et al. 1999, Hughes and Madden 2003). A further complication for calculating sensitivity, specificity and overall accuracy with the Pheloung system is whether to call species that score as 'further evaluate' weeds or non-weeds. To enable "standardised" comparisons of the discriminatory power of different screening systems/tests, Receiver Operating Characteristic (ROC) curves can be generated (Hughes and Madden 2003, Caley and Kuhnert *in submission*). ROC curves are a plot of sensitivity versus (1 – specificity) for all possible cut-off scores in a screening system. They are independent of the weed and non-weed proportions in the test data set. Figure 4 shows examples of ROC curves (from Caley and Kuhnert *in submission*). The better the performance of the screening system, the closer the curve passes to the upper left-hand corner. The area under the curve is a measure of performance, with an area of 1 having perfect accuracy and an area of 0.5 having no discriminatory ability (Caley and Kuhnert *in submission*).

Whilst ROC curves provide a better comparative measure of performance than overall accuracy, they still do not indicate "real world" performance when a screening system is being used routinely. This is due to differences in the 'base rate' of data sets used for test development and actual screening. The base-rate is the prevalence of a phenomenon in a population under study (Lonsdale and Smith 2001). For the application here, the base rate is what percentage of plant imports are likely to become weeds. The majority of test data sets for developing weed screening systems have had proportions of weeds much greater than the actual proportion of plant species introductions that become weeds. There are various estimates for this actual proportion. Panetta et al. (1994) estimated a weediness rate of 2% for all plant introductions to Australia. However, this figure has been recently estimated at *ca*. 7% by Virtue et al. (2004). Because of the low incidence of species becoming weeds, systems claiming a high accuracy of predicting weediness may actually predict many more false positives than true positives (Smith et al. 1999). Hence the "real world" base-rate must be considered if one is to get a true picture of how effective weed screening systems are in detecting actual weeds and non-weeds.

BOX 1 (cont'd)

Figure 4 Hypothetical Receiver Operating Characteristic (ROC) curves of test sensitivity, the probability of correctly rejecting a weed [Pr(Reject | Weed)], *vs.* (1 – specificity), the probability of falsely rejecting a non-weed [Pr(False Positive)]. The four lines relate to tests of varying performance, ranging from no discriminatory power (solid 45^{o} line) to high discriminatory power (dashed line passing through upper left-hand corner of plot). From Caley and Kuhnert (*in submission*) with permission.



BOX 2 Studies on the technical performance of the Pheloung system

Following is a brief literature review of the major outcomes from various international studies that have examined the Pheloung system.

Smith 1999, Smith et al. 1999, Lonsdale and Smith 2001

- Estimated sensitivity of the Pheloung system as 70% and specificity 53%, based on data in Pheloung (1995). Sensitivity varied between plant families (e.g. was 90% for Asteraceae but only 42% for Fabaceae).
- The best case overall accuracy of the Pheloung system was 85%, which was greater than two other weed screening systems investigated. However, this calculation treated species falling into the 'further evaluate' category as predicted to be weeds. Excluding this category dropped overall accuracy to 66%.
- For a weed risk assessment model with an assumed accuracy of 85% and a base-rate probability of weediness of 2%, only 17/164 (i.e. 10%) of predicted weeds would be true positives. The remaining 90% would be false positives. This low accuracy was deemed satisfactory provided that the economic loss caused by introducing a weed was at least eight times that from not introducing a harmless plant species that is potentially useful.

Pheloung et al. 1999

- The Pheloung system was slightly modified for New Zealand, changing question 2.04 to 'equable climates' (rather than 'arid climates') and question 4.10 to 'a range of soil conditions (rather than 'infertile soils'). The cut-off scores remained the same.
- 195 taxa were assessed using the New Zealand system and independently classified by 13 NZ experts as non-weed, minor weed or major weed. The proportions of 'accept', 'evaluate' and 'reject' from the system were 16%, 21% and 63% respectively, which essentially mirrored the expert's rankings of non-, minor and major weeds. No taxon which was considered a major weed (including all noxious weeds) scored as 'accept'. However, there were some differences in the taxa within each classification, with only 64% of taxa in common. Sensitivity was *ca.* 83% and specificity *ca.* 70%.
- The NZ system rejected some commercially important species that the expert ranking had considered minor weeds/'evaluate' (including red clover and perennial ryegrass). Likewise the system rated other commercial plants as 'evaluate' when the experts ranked them as non-weeds (including sunflower, potato and maize). Such rejections/further evaluations of some commercially important taxa was expected due to some common attributes of weeds and some agricultural species (e.g. for persistence).

Daehler and Carino 2000, Daehler et al. 2004

- The performance of the Pheloung system (modified in a similar manner to New Zealand) was compared with a North American system for woody plants (Reichard and Hamilton 1997) and a system designed for the South African fynbos (Tucker and Richardson 1995). 54 invasive and 57 historically non-invasive species in Hawaii were tested (although the modified Pheloung system test species data set was reduced to 96 to remove species that had been used in the original development of the model).
- The modified Pheloung system had the highest sensitivity, rejecting 93% of invasive species and accepting none. Specificity was 54% (non-invaders accepted), with a further 32% scored as 'evaluate'.
- The modified Hawaii system was tested again (Daehler et al. 2004) with 172 taxa introduced to Hawaii or other Pacific islands. These were classed by 25 experts (where the species was known to an expert) into 'major pest', 'minor pest' or 'not a pest', for both agricultural and natural ecosystems.
- In this second test the modified Hawaii WRA accepted 5% of major pests (1/22 species) and 16% of minor pests (7/45 species). 66% of non-pests were admitted (69/105 species), an improvement on the previous test's (Daehler and Carino 2000) specificity of 54%.
- The use of a decision tree for second-stage screening of 'further evaluate' species decreased these from 24% to 8%, increased non-pest admissions (i.e. specificity) from 66% to 85% and increased minor pest admissions from 16% to 33%.

BOX 2 (cont'd)

Hughes and Madden 2003

- The original training set for the Pheloung system was evaluated using various statistical approaches. The serious and minor weeds were combined, giving 286 weed species and 84 non-weed species for analysis.
- The probability of weediness was determined using logistic regression and this was plotted against the Pheloung system's score. At 50% probability of weediness (i.e. considered a weed if >50% probability) the cut-off score was –1, with a sensitivity of 94% and a specificity of 51%.
- Alternatively, the probability of weediness was determined using a discriminant function. At 50% probability of weediness the cut-off score was 4, with a sensitivity of 76% and a specificity of 85%. This approach had greater discriminatory power than the logistic regression approach.
- Using a sensitivity of 76%, a specificity of 85%, a weediness base rate in the general plant population of 2%, the probability that a predicted weed was an actual weed (at the cut-off score of 4) was 0.094. So there was a less than 1 in 10 chance of predicting an actual weed, a result similar to Smith et al. (1999).

Caley et al. 2005

- The Pheloung system doesn't provide probabilities of weediness, which are dependent on specificity, sensitivity and base rate. A Beta distribution was used to model variation in the base rate, with a mode of 0.02, mean of 0.05 and 99% quartile of 0.17 (based on figures in Smith et al. 1999). Two alternative statistical approaches (logistic regression and bootstrap analysis) were used to examine the probability of weediness for various WRA scores.
- The probability of weediness [P(W+)] began increasing at a WRA score of 0, but the 'further evaluate' class had a low P(W+) with only 2% at a score of 1 increasing to 6.4% at a score of 5. There was also high variation (i.e. large uncertainty intervals) in P(W+) for the 'further evaluate' class.
- There was a rapid rise in P(W+), with low variation, as the WRA score increased from 6.

Caley and Kuhnert *in submission*

- A ROC curve (see Box 1) for the original data training set of the Pheloung system had an area under the curve of 0.89, with little gain in sensitivity (i.e. slow increase above 90%) as specificity dropped below 50%. This indicated high discriminatory power.
- A classification tree approach was examined as an alternative to the additive scoring method of the Pheloung system. The original training set was used with 286 weeds (serious and minor weeds combined) and 84 non-weeds.
- A simple classification tree was developed with just four criteria:
  i. Evidence of naturalisation beyond native range
  ii. Documented repeated introduction outside natural range
  iii. Level of domestication
  iv. Ability for unintentional human dispersal
- The Pheloung system performed significantly better than the classification tree (area under curves of 0.89 vs. 0.81 for ROC curves). However, the classification tree offers substantial time savings in assessment. The results should also be treated with caution as the test data set had relatively few non-weeds, and bias due to not taking account of the "real world" base rate probably overestimated the performance of both approaches.

Jefferson et al. 2004

- Three models were compared for use in the Chicago Botanic Gardens; the Pheloung system (modified for Chicago's climate and soils), a modified version of Reichard and Hamilton (1997) and a draft shortened version of the Pheloung system (by D. Panetta and P. Williams). Twenty invasive and 20 non-invasive species of the same genus/family and growth form were compared, covering a range of forbs, shrubs, vines and trees.
- The Pheloung system had a sensitivity of 100%, with all 20 invaders being predicted. However, 9/20 non-invaders were rejected (specificity 55%) and the remainder scored 'further evaluate'.
- The Pheloung system was modified by excluding scores for Climate and Distribution questions 2.01-2.05 (but maintaining the same scoring for 3.01-3.05). The sensitivity remained at 100%, but gains were made for non-invasives with only 15% (3/20) of non-invaders being rejected and 45% scoring as 'further evaluate'.
- The shortened Pheloung system was best for non-invasives with 95% specificity, but sensitivity was reduced to 65% (i.e. 35% invasives accepted).

BOX 2 (cont'd)

Paul Pheloung (pers. comm.)

- The Weeds CRC has been examining the BA WRA database of 1446 species to test the consistency and association with weediness for each question in the system. Consistency has been examined by recalculating WRA scores with the question of interest removed and then determining whether there is a statistically significant relationship between the overall score and question score. Association with weediness has been examined by classifying species as a weed or non-weed elsewhere and then determining if the average score for the question of interest is significantly different for each class.
- Preliminary analyses have found that over half the questions passed both tests. Ten questions did not pass either test (based on the statistical methodology used to date). Some of these ten questions did not pass due to limited information being available (e.g. substantial reproductive failure in a species' native habitat) or being a rare plant attribute (e.g. parasitic). Some of these questions seemed to be inconsistently interpreted (e.g. domestication). Some were destined to be mostly answered as 'yes' (e.g. produces viable seed). Dispersal questions were noted to generally lack independence and their scoring could cancel out each other (e.g. a 'yes' to bird dispersal [score of +1] would generally be associated with a 'no' to wind dispersal [score of -1]).

The 49 questions

Each of the 49 questions (Figure 1 and Appendix 3) were individually tested for correlation with weediness/non-weediness in the development of the Pheloung WRA system, and have been based on observational and experimental studies (Pheloung *et al*. 1999).

There is some contention over similarities in scoring between what makes a weed and what makes a desirable pasture plant (Bennett and Virtue 2004). These include questions on climate (2.01-2.05), infertile soil (4.10), produces viable seed (6.02), and soil seedbank (8.02). There are valid concerns that some species have scored as 'further evaluate' when their close relatives are widely naturalised and are considered to have minimal impacts, such as annual pasture legumes (Emms *et al*. 2004).

There was stakeholder concern expressed in Chapter 2 about the impact of non-responses to questions and whether there is potential to bias results based on the number of questions answered and which ones are answered. However, the Pheloung WRA system will not give an outcome unless a minimum number of questions are answered for the three main sections of biogeography, undesirable attributes and biology/ecology (Pheloung 1995).

There was also stakeholder concern expressed in Chapter 2 about the appropriateness and clarity of some questions. The database that has been developed by AQIS/BA since the implementation of the WRA System is currently being analysed (Paul Pheloung pers. comm.) to determine if all 49 questions warrant continued inclusion in the Pheloung system, and whether weightings for particular questions would gain better precision. Preliminary results (Box 2) indicate that some questions may have limited value and other questions may

need changes in scoring. The final outcomes of this analysis should be considered before any changes to the questions are considered.

Implementation of the Pheloung system within BA

Variation between assessors in answering questions for the same species is a valid concern of stakeholders. Whilst the yes/no choice appears objective, it can still be open to subjective interpretation of literature. This was observed in a 2001 draft analysis of selected species held within Australian Genetic Resource Centres (GRCs), undertaken by external contractors.

Adequate resourcing, quality control and ready access to current literature (including nomenclature) is vital to minimise anomalous outcomes emerging from the current system. Ongoing improvements by BA to quality control and communication enable more consistent and transparent outcomes for the Pheloung System. There is formal documentation of the basis for answering questions as yes/no (e.g., as citable publications). BA weed risk assessors receive training and ongoing technical supervision. Proponents of plant imports are able to review scoring of species where there is contention.

Potential Improvements to the Pheloung WRA System

The additive approach in the Pheloung WRA system has performed robustly (see Box 2) and is relatively easy to comprehend for people without skills in weeds or mathematical modelling. However, it is possible that improvements could reduce the potential for false positives (i.e. true non-weeds predicted to be weeds) and the number of species scoring as 'further evaluate'. Potential improvements to the Pheloung WRA system are listed below, in order of increasing complexity. Each would need proper scientific/statistical investigation and testing to determine its merits. The initial training dataset would also need to be supplemented by more assessments of non-weeds in testing any revised system.

- Raise the minimum number of questions which must be answered before a score can be generated. Whilst this may result in an increase in the number of 'accept' or 'reject' outcomes, it is highly dependent on the amount of information available on the species. As lack of information on a species is a limiting factor in achieving a WRA outcome, raising the minimum number of questions could in fact increase the number of 'insufficient information' outcomes (i.e. no score can be generated).
- Progressively raise the 'accept' score to greater than zero as more of the 49 questions are answered. Key questions would need to be identified for this. Questions relating to consequences (i.e. potential weed impacts) would be most important.
- Rationalise the number of questions within the Pheloung system, to those which can be readily answered and which have a significant contribution to the final outcome. Alternatively (or in addition), revise the scoring assigned to some questions. This is pending the outcomes from the current analysis of BA data by the Weeds CRC (Paul Pheloung pers. comm.).
- Provide discrete likelihood and consequence scores, from which is determined a final risk score. Risk is weighing up of the likelihood and consequences of an event (AS/NZS 4360, 2004). In this instance the event is a new weed, the

likelihood is whether the plant species could naturalise and spread and the consequence is what impacts the species would have as a weed. The 49 questions could be categorised as to whether they relate most to likelihood or consequence. It would be useful to see if species that fall readily into 'reject' do so because of a positive score for many of the consequence questions, whereas some species end up as 'further evaluate' due to the likelihood questions.

- Develop a second weed screening system for 'further evaluate', as done by Daehler *et al*. 2004. This was a decision tree approach, with alternate flow charts for trees/small shrubs and herbs/small shrubs. It significantly reduced 'further evaluate' species and also reduced the incidence of false positives. This may help decisions on species which, based on the experience of closely-related species in Australia, would not be expected to pose a significant weed impact.
- Provide an estimate of the probability of a species becoming a weed in Australia, rather than a score which needs to be interpreted (e.g., Hughes and Madden (2003) and Caley *et al*. (2005). This allows for and provides a clear guide on what level of risk Australia is prepared to accept in determining the import status of plant imports. A probabilistic approach to estimating the likely weediness of a plant species could be developed by taking account of the actual base-rate for weediness in Australia (a function of plant families, genera and plant industries). This information is currently being prepared by Randall (2005).
- Develop an alternative predictive weed screening process, such as a filter system suggested in Chapter 2. Caley and Kuhnert (in submission) have presented an alternate classification tree/flow chart approach with quite good accuracy. However, the four criteria selected may have been a property of the species mix in the original training data set for the Pheloung system. The first criterion of history of naturalisation is highly correlated to past weediness, but this would not work well for species new to cultivation. Likewise the criteria on repeated introductions and domestication favours species that have long been in cultivation. Unintentional human dispersal is highly correlated to weediness (Virtue *et al*. 2004), but this relates to weeds associated with human activities. None of the four criteria relate directly to consequences (i.e. potential weed impacts). The classification tree approach should be investigated further, but with a larger dataset of equal proportions of randomly selected weeds and non-weeds.

Weed risk assessment is an evolving science. WRA systems should be continually reviewed and improved as our knowledge on factors driving weed invasions expands, and as risk assessment techniques increase in precision.

Key Recommendations

1. That a revised version of the Pheloung WRA system be developed that maintains high levels of sensitivity (high rate of true weed predicted), significantly increases specificity (higher rate of true non-weeds predicted) and minimises 'further evaluates'.

2. That internal standards for using the Pheloung WRA system be established with regards to documentation, consultation, efficiency, quality control and

external review and ensure that sufficient, ongoing resourcing is provided to meet these standards.

CHAPTER 5 - TIER 3 OF THE ASSESSMENT PROCESS

Background
The inclusion of provision for a third Tier to the Weed Risk Assessment (WRA) process was recognition that there would be circumstances where there was insufficient information to make a definitive finding (i.e. accepted or rejected for importation). In these circumstances additional information would be required and a mechanism to allow this information to be collected and brought into the evaluation process would be desirable. Any activity that went beyond the application of the Pheloung WRA system using readily available information from literature sources was regarded as being part of Tier 3.

Tier 3 concept and relationship with Tiers 1 and 2
Application of the WRA System can have four outcomes following the process outlined in Chapters 3 and 4. They can be:

- 'accepted' and added to the permitted list (with the result recorded in ICON)
- 'rejected' (with the outcome of the assessment recorded in ICON)
- classified as 'further evaluate', or
- classified as 'insufficient information'

The relationship between Tiers 2 & 3 that was developed when the current process was conceived is shown in Figure 6.

In practice, plants which meet the minimum information test are classified as 'further evaluate' when they have a score of 1 to 6 on the Pheloung WRA system (Pheloung, 1995). Once placed in this category, plants are effectively managed for operational plant introduction purposes as prohibited plants. This holds until there is a reassessment of their status following additional information becoming available.

In the absence of a "formal" operational Tier 3 to the WRA System, classification as 'further evaluate' effectively prohibits importation. While this is the current reality, it is important to recognize that an operational Tier 3 process can be anticipated and so it should be permissible to maintain seed supplies of 'further evaluate' species in appropriately approved and managed quarantine storage to facilitate this future phase.

The Tier 3 phase of the WRA aims to allow the collection of specific information by focused data collection where literature sources are inadequate. The unstated philosophy behind the 'further evaluate' category is that the precautionary approach will not be compromised by the lack of information. However, if this lack of information should be resolved, it is not a basis for longer term rejection.

There are two distinct cases of information needs to resolve 'further evaluates'. Case one is a lack of information to answer a sufficient number of questions (this also applies to species classed as having 'insufficient information'). Case two is where the scoring remains as 'further evaluate' despite answering the minimum number of questions.

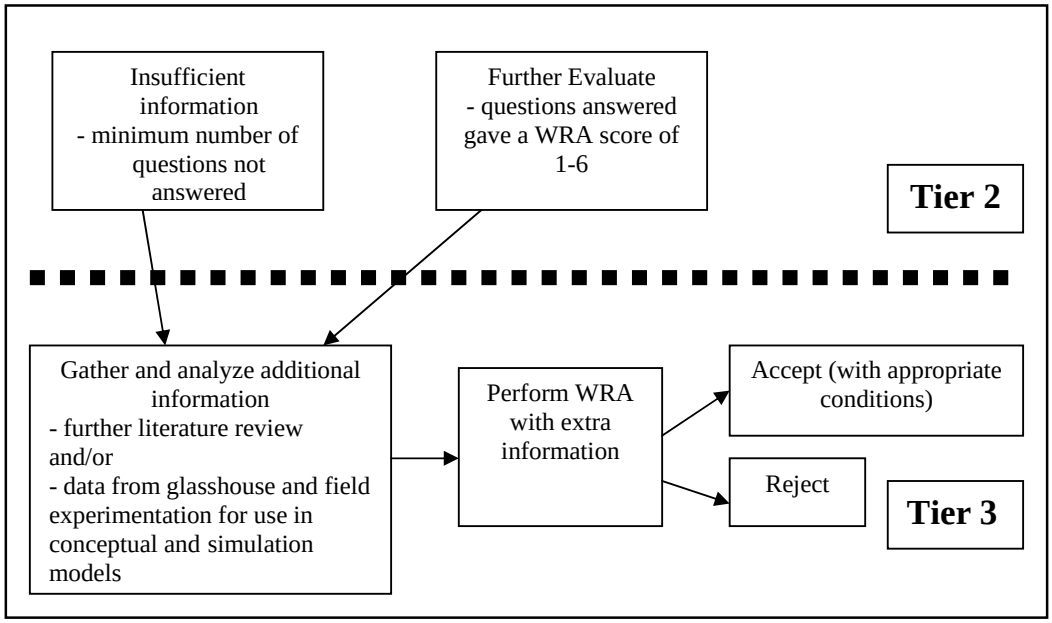


Figure 6. Conceptual model of the planned relationship between Tier 2 & 3 of the WRA process (yet to be implemented).

In case one where there is insufficient information to answer a majority of questions within the WRA System (to get a clear 'accept' or 'reject'), the deficiency can be resolved either by an intensified search of current literature or by undertaking a limited data collection process, probably glasshouse based.

In the case of intensified searching, there are examples of cooperative activity between staff of BA and plant importers or scientific experts to put together sufficient information to make a full evaluation of weed risk (in circumstances where an initial scan of information available appeared unpromising). This is an adaptation of the standard Tier 2 process and access to this pathway should be more clearly highlighted in descriptions of the current operational model. The information needs of this process become clear from the gaps exposed while applying the WRA System and can be readily specified through consultation with BA. It is clearly important to recognize that the final responsibility for synthesis and analysis of collected information entering the WRA System resides with staff at BA.

If an intensified literature search is unsuccessful, the only path forward is active data collection. Operational protocols to govern active collection of additional biological information to fill information gaps are yet to be established. Quarantine procedures similar to those needed for case two (below) will be required if the information collection is to be undertaken in Australia.

In case two where the minimum number of questions are answered but the scoring remains in the 'further evaluate' range, other approaches to resolve the weed risk status of the plant species will be needed. The most obvious pathway would be to undertake specific studies under highly controlled conditions, preferably in a glasshouse. However, additional information needed to resolve uncertainty will not

always be amenable to glasshouse studies and under some circumstances field studies may be needed. There also remains considerable uncertainty over what traits to measure to predict weediness, beyond those listed in the current Pheloung WRA system. Intensive studies by the Weeds CRC have not been able to identify a manageable number of broadly applicable, highly predictive traits (Graeme Hastwell pers. comm., Jason Emms pers. comm.). In all cases there would be a need for supervision of both the scientific validity of the approach and outcomes as well as the safety of the process in eliminating any risk of escape (Walton, 2001).

Requirements for an operational Tier 3

To date, no plants have been re-evaluated and reclassified through the Tier 3 process following the collection of additional biological information. From the importation and demand-driven side, there has been recognition that it is more efficient in the short term to direct WRA resources to assessments based on existing data before embarking on new detailed bio-physical studies. Application of the WRA processes has been undertaken with sufficient flexibility to allow plant importers and scientific specialists to add their information to the formal desk top studies (adaptation of Tier 2 protocols).

The application of the more flexible Tier 2 process, while desirable, clearly does not change the requirement for a new data collection step (Tier 3) in limited circumstances and this is yet to become operational. In the absence of this process, plants in the further evaluate class are effectively the same as prohibited species.

A clear outline of Tier 3 processes has yet to be formalized but a number of issues of design and coverage have been widely canvassed. The resource demands for implementation of Tier 3 evaluation case by case are likely to be greater than Tier 2, and there is a need to determine from where these costs are to be met. These costs are likely to have the effect of limiting the number of instances in which Tier 3 protocols are invoked. Thus, there is no expectation that all cases rated further evaluate will be rapidly processed leading to reclassified as accept or reject. The accumulation of large numbers of plants on a further evaluate list will not be a symptom of system ineffectiveness as long as access to Tier 3 processes are available.

If, as anticipated, there are low number of cases requiring Tier 3 evaluation a more information intensive approach can be justified. This would allow more detailed investigation into the areas covered in the current WRA questionnaire as well as additional areas. The additional areas could cover aspects of potential of introductions for weed impact and management in addition to the current focus on potential to naturalize.

There is now a need to finalize a process that maximizes weed risk avoidance but can be implemented at reasonable cost, given that importers are likely to be expected to fund Tier 3 activities. The system needs to allow for and involve the following elements.

Off shore evaluation
Collection of additional information may in some circumstances be possible offshore thereby eliminating quarantine concerns. This may be of particular value where the required information can only be delivered from field sites. Where information is being collected specifically for Australian WRA purposes the design of experimental protocols should reflect the data input need of the Pheloung WRA system and direct input by BA into protocol development would increase the efficiency of this process.

Glasshouse evaluation
Effective Tier 3 activities will depend on the availability of facilities that meet the quarantine specification for such installations. Where possible, these should be the same as for general plant quarantine programs to allow multiuse of glasshouse facilities.

It should be recognized that glasshouse conditions will not always allow plants to develop as they would under field conditions and only a subset of plant characteristics can be measured. The design of glasshouse experiments would require the agreement of BA and AQIS.

Field evaluation
A key feature of field trials is the development of design and protocols to prevent escapes of plants or seeds. Given the range of reproductive strategies and potential amongst plants, this would require a case by case approach. Priority would be given to measuring traits established as data inputs of plant weediness models to allow general conclusions to be drawn from short-term data collection efforts. The design and security of these trials would require the input of BA and the ongoing management and involvement of AQIS inspectors.

Benefit/cost analysis
A quantitative process which incorporated an assessment of the potential economic, environmental and amenity benefits of a plant introduction, against the costs of weediness, may add depth to the assessment. This would demand information that would predict likelihood of naturalization but also the impact of that outcome on economic, environmental and amenity values. This would draw in some assessment of the characteristics of the introduced plant relative to existing established weeds. However, as noted in chapter 2,the inclusion of economic elements to a quarantine process would contravene current international trade agreements to which Australia is a signatory. It is therefore not possible to include this kind of analysis.

Within species variation
An effective Tier 3 process needs to have sufficient operational flexibility to allow evaluation of natural or selected variants of species that have a set of traits that allow them to be distinguished from species that are either in the further evaluate or reject class. This may require both literature review and physical experimental evidence of lowered weed risk characteristics.

An alternate assessment system for Tier 3

Daehler *et al*. (2004) developed a second stage assessment process for species that were categorized as 'further evaluate'. A short, simple decision tree, with separate questions for woody and herbaceous species gave marked improvements in terms of a reduction in 'further evaluates' and an increase in non-weed admissions. However, there was a moderate increase in the acceptance of minor weeds. There is merit in investigating the broader applicability of the decision tree of Daehler *et al*. (2004) to Australia. If robust it would be considerably cheaper than experimentation.

Resources for Tier 3 development

Allocation of resources for Tier 3 activities requires consideration of two phases, the process development stage and the on-going operation phase. It would also require consideration of where these resources should come from, given the expectation that users would fund information gathering processes associated with progressing the 'further develop' category.

Third Tier assessments, if conducted in Australia, would need to be conducted in a quarantine secure manner. This would require AQIS involvement in issuing permits, registering and auditing facilities, and monitoring trials. Current Commonwealth Government policy is that AQIS operates on a full cost recovery basis.

There is a need for resources to be available to reactivate the development of Tier 3 processes and protocols. There is equally a need for resources to be available on the user side to support the implementation of Tier 3 protocols as they become available. The demand for assessment of plants of potential use in salinity management (Ewing and Dolling 2004) through activities of the CRC for Plant-base Management of Dryland Salinity provides one such opportunity. Their collaboration with the CRC for Australian Weed Management provides the skill base to implement Tier 3 protocols and provide feedback on their use which will allow improvement and refinement for wider application.

Conclusions

Operational Tier 3 processes and protocols need to be developed and tested in collaboration with users to allow collection of additional biophysical information that will allow reassessment of plants in the 'further evaluate' class. This development will require commitment of resources in the short term to the process development stage and in the longer term to interface with users to determine the appropriate strategy for data collection and supervise its implementation.

In the absence of an operational Tier 3 process which would allow plants classed as 'further evaluate' to progress, provision should be made to allow seed of such plants to be stored securely in certified quarantine facilities until their longer term status is established.

Tier 3 activities are clearly more resource intensive than Tier 2 activities and attempts should be made to minimize the numbers of plants classified as further evaluate. Current processes to allow and encourage importers and scientific specialists to collaborate in identifying sources of information as input to Tier 2 assessments, should be actively promoted.

Consideration needs to be given to the possibility of expanding the evaluation criteria of plants entering Tier 3 evaluation to include an assessment of likely benefits as well as the costs of a plant introduction that might result from them becoming weeds. In addition consideration needs to given to the possibility of including a process to evaluate the weed impact of a plant introduction alongside the risk of it becoming naturalized.

Current programs and activities within the CRC for Australian Weed Management in collaboration with a key user (CRC for Plant-base Management of Dryland Salinity) provide a skill and resource base to aid in the development and testing of Tier 3 processes and protocols prior to their wider adoption by importers. A workshop with the two CRCs, BA and AQIS is planned for early 2006 to advance development of Tier 3.

Key recommendations

1. That resources be allocated to develop, test and operate a Tier 3 component to the WRA process as originally envisaged when the current scheme was introduced.
2. That the Australian Government develop a policy on how the costs of developing and operating a Tier 3 methodology are to be funded.
3. That Tier 3 operating protocols be established that allow additional information to be collected to answer the thresholds number of questions required of the WRA process.
4. That processes be developed that allow plants in the further evaluate category (Pheloung WRA System score between 1 and 6) to be subject to additional risk analysis prior to categorisation as permitted or prohibited.

CHAPTER 6 - SUMMARY AND RECOMMENDATIONS

The WRA System has been operating since 1997, and while some stakeholders are critical of aspects of the WRA system, there is no serious suggestion that the system should be abandoned or replaced with another process. It is generally agreed that the current system has demonstrated that it is robust and effective. The main issues raised by stakeholders relate to:

- Concerns regarding prevention of introduction of 'non weedy' new plant material which could provide substantial benefits to agriculture and the environment,
- The need for the system to deliver consistent and transparent results.
- The need for the system to comply with the requirements of the EPBC Act.
- Continued need to prevent entry of potentially invasive species which affect the environment.
- Continued need to meet the needs of the commercial sector.

Some plant importers believe that the WRA system may be too risk averse and also may deliver some inconsistent results. The Review team believes that this may have partly arisen due to the 'bulk assessment trial' which was not successful. Many of the concerns could also be addressed by making the process more transparent.

The Review Group has considered these issues and has agreed that, overall, the WRA system is meeting its objectives to reject weeds, but in doing so it may also be rejecting non-weedy plants. There is a strong case to refine the system and its implementation to retain its ability to detect and reject true weeds, while increasing its capability to accept non-weeds.

The Review Group also identified the importance of adequate resources being available from Government to support and administer the WRA system.

Tier 1

One of the important issues identified was the need for importers to accurately identify the species, Family or genus before import can be assessed. A related issue was the possible use of "name shopping" (the intentional misnaming of a plant using a name known to be on the permitted list for what is in reality an unassessed or quarantine species) by importers, and that AQIS and the Steering Group on BIOSEC are advised of the concerns.

The second phase in the decision making process involves three decisions :

1. Are there existing quarantine procedures?
2. Is the species present in Australia?
3. Is the species under Official Control?

as set out in the diagram on page 25 of this report.

In this context the Review Group supported the review of the Permitted Seeds List currently being undertaken by BA.

The Review Group is also concerned about the weed risk of material held in Botanic Gardens, CRCs and other research organisations, and agreed that this should be considered by the current national biosecurity planning process.

The skills required, both by the proponent and the assessor, were considered, and it was agreed that assessors should have adequate access to the training, materials and resources required for weed risk assessment.

Tier 2

Tier 2 of the WRA process is the use of the Pheloung WRA System to predict the potential weediness of a new plant species, as a result of the Tier 1 process indicating that a WRA should be performed.

The Pheloung WRA System was examined in considerable detail, and it is agreed that this system has performed robustly. Nevertheless, there is always scope for improvement in any system, and some specific suggestions for improvement have been made, including:

- Raise the minimum number of questions which must be answered
- Progressively raise the 'accept' score as more questions are answered
- Rationalise the number of questions by excluding those which cannot be readily answered or are not significant
- Provide discrete likelihood and consequence scores, from which is determined a final risk score
- Develop a second weed screening system for 'further evaluate'
- Provide an estimate of the probability of a species becoming a weed, rather than a score
- Develop an alternative predictive weed screening process such as a filter system.

Tier 3

The third tier of the WRA process, comes into operation when the outcome of the Pheloung WRA System indicates that the plant concerned needs to be further evaluated before a decision can be made, or that there is insufficient information to make a decision.

There is currently no "formal" operational methodology for Tier 3, and the Review Group has agreed that processes and protocols need to be developed and tested in collaboration with users to allow collection of additional biophysical information that will allow reassessment of plants in the 'further evaluate' class. This development will require commitment of resources in the short term to the process development stage and in the longer term to interface with users to determine the appropriate strategy for data collection and supervise its implementation.

In the absence of a formal operational Tier 3 process which would allow plants classed as 'further evaluate' to progress, provision should be made to allow seed

of such plants to be stored securely in certified quarantine facilities until their longer term status is established.

Summary of Key Recommendations

1. That AQIS and the Steering Group on BIOSEC be advised of the Review Group's concerns that the practice of "Name shopping" may result in material that should undergo a WRA, not in fact doing so.

2. That a link to the permitted seeds list, as contained in the relevant quarantine legislation, be provided on the AQIS website.

3. That the issues relating to monitoring for and assessing the weed risk of new plant species within Australia's border, particularly material held by Botanic gardens, GRCs and other research organisations, need to be considered by the current national biosecurity planning process.

4. That BA ensure their assessors have adequate access to the training, materials and resources required for weed risk assessment.

5. That a revised version of the Pheloung WRA system be developed that maintains high levels of sensitivity (high rate of true weed predicted), significantly increases specificity (higher rate of true non-weeds predicted) and minimises 'further evaluates'.

6. That internal standards for using the Pheloung WRA system be established with regards to documentation, consultation, efficiency, quality control and external review and ensure that sufficient, ongoing resourcing is provided to meet these standards.

7. That resources be allocated to develop, test and operate a Tier 3 component to the Pheloung WRA System as originally envisaged when the current scheme was introduced.

8. That the Australian Government develop a policy on how the costs of developing and operating a Tier 3 methodology are to be funded.

9. That Tier 3 operating protocols be established that allow additional information to be collected to answer the thresholds number of questions required of the Pheloung WRA System.

10. That processes be developed that allow plants in the further evaluate category (Pheloung WRA System score between 1 and 6) to be subject to additional risk analysis prior to categorisation as permitted or prohibited.

REFERENCES

AS/NZS 4360 Standards Australia/Standards New Zealand (2004). *Risk Management*. (Standards Australia International Ltd, Sydney)

Bennett, S.J., Ayres, J., Dear, B.S., Ewing, M.A., Harris, C., Hughes. S., Mitchell, M., Moore, G., Nie, Z., Reed, K., Sandral, G.A., Slattery, J., and Snowball, R. (2003) Perennial pastures for the recharge areas of southern Australia, CRC for Plant-based Management of Dryland Salinity ISBN:1740521005

Bennett, S.J. and Virtue, J.G. (2004). Salinity mitigation versus weed risks - can conflicts of interest in introducing new plants be resolved? *Australian Journal of Experimental Agriculture, Vol 44, No 12, Dec 2004.*

Caley, P., Lonsdale, W.M. and Pheloung, P.C. (2005). Quantifying uncertainty in predictions of invasiveness, with emphasis on weed risk assessment. Biological Invasions (in press).

Caley, P. and Kuhnert, P. (in submission). Application and evaluation of classification trees for screening unwanted plants.

Daehler, C.C. and Carino, D.A. (2000). Predicting invasive plants: prospects for a general screening system based on current regional models. *Biological Invasions* 2, 93-102.

Daehler, C.C., Denslow, J. S., Ansari, S. and Kuo, H-C. (2004). A risk assessment system for screening out invasive pest plants from Hawaii and other Pacific Islands. *Conservation Biology* 18(2), 360-368.

Dear, B.S., Moore, G.A. and Hughes, S.J. (2003). Adaptation and potential contribution of temperate perennial legumes to the southern Australian wheatbelt: a review. *Australian Journal of Experimental Agriculture* 43, 1-18.

Emms, J., Virtue, J.G., Preston, C. and Bellotti, W.D. (2004). Do all legumes pose the same weed risk? Development of a method to evaluate the risk of introduced legumes to temperate Australia. *In* 'Proceedings of the 14th Australian Weeds Conference', Eds B.M Sindel and S.B. Johnson, pp. 105-8 (Weed Society of New South Wales, Sydney).

Ewing, M. A. and Dolling P. Herbaceous perennial pasture legumes: Their role and development in southern Australian farming systems to enhance system stability and profitability (2003) *In* New Perennial Legumes ed. Bennett S. J., pp.3-14, University of Western Australia Press.

FAO (1997). *Glossary of phytosanitary terms.* Secretariat of the International Plant Protection Convention, Food and Agriculture Organization of the United Nations, Rome.

FAO (2000) *Report of the ICPM open-ended working group on official control*, 22-24 March 2000.

Groves, R. (1997) *Recent Incursions of Weeds to Australia 1971-1995*, CRC for Weed Management Systems.

Hazard, W.H.L. (1988). Introducing crop, pasture and ornamental species into Australia – the risk of introducing new weeds*. Australian Plant Introduction Review* 19, 19-36.

Hughes, G., and Madden, L.V. (2003). Evaluating predictive models with application in regulatory policy for invasive weeds. *Agricultural Systems* 76, 755-774.

Jefferson, L., Havens, K. and Ault, J. (2004). Implementing invasive screening procedures: the Chicago Botanic Garden model. *Weed Technology* 18(5), 1434-1440.

Lonsdale, W.M. (1994) Inviting trouble: Introduced pasture species in northern Australia. *Australian Journal of Ecology* 19, 345-354.

Lonsdale, W.M. and Smith, C.S. (2001). Evaluating pest-screening systems – insights from epidemiology and ecology. *In* 'Weed Risk Assessment', Eds R.H. Groves, F.D. Panetta and J.G. Virtue, pp. 52-60 (CSIRO Publishing, Collingwood, Australia).

Nairn, M.E., Allen, P.G., Inglis, A.R. and Tanner, C. (1996) *Australian Quarantine*: a *shared responsibility*, Department of Primary Industries and Energy, Canberra.

Panetta, F.D. (1993). A system of assessing proposed plant introductions for weed potential. *Plant Protection Quarterly* 8, 10-14.

Panetta, F.D., Pheloung, P.C., Lonsdale, M., Jacobs, S., Mulvaney, M. and Wright, W. (1994). Screening plants for weediness: a procedure for assessing species proposed for importation into Australia. A report commissioned by the Australian Weeds Committee.

Pheloung, P.C. (1995) Determining the weed potential of new plant introduction to Australia. Draft report to the Australian Weeds Committee and the Plant Industries Committee. (Agriculture Protection Board: Western Australia).

Pheloung, P.C., Williams, P.A. and Halfoy, S.R. (1999). A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. *Journal of Environmental Management* 57, 239-251.

Pheloung, P.C. (2001). Weed risk assessment for plant introductions. *In* 'Weed Risk Assessment', Eds R.H. Groves, F.D. Panetta and J.G. Virtue, (CSIRO Publishing, Collingwood, Australia).

Randall, R.P. (2005) 'Plants Database', unpublished database (Western Australian Department of Agriculture, Perth).

Reichard, S.H., and Hamilton, C.W. (1997). Predicting invasions of woody plants introduced into North America. *Conservation Biology* 78, 171-181.

Sinden, J., Jones, R., Hester, S., Odom, D., Kalisch, C., James, R. and Cacho, O. (2004). 'The economic impact of weeds in Australia' (CRC for Australian Weed Management, Adelaide).

Smith, C.S. (1999). Studies on weed risk assessment. M. App. Sci thesis, University of Adelaide.

Smith, C.S., Lonsdale, W.M. and Fortune, J. (1999). When to ignore advice: invasion predictions and decision theory. *Biological Invasions* 1, 89-96.

Spafford Jacob, H., Randall, R. and Lloyd, S. (2004). 'Front door wide open to weeds: an examination of the weed species permitted for import without weed risk assessment.' (WWF Australia, Sydney).

Tucker, K.C. and Richardson, D.M. (1995). An expert system for screening potentially invasive alien plants in South African fynbos. *Journal of Environmental Management* 44, 309-338.

Virtue, J.G., Bennett, S.J. and Randall, R.P. (2004). Plant introductions to Australia: How can we resolve "weedy" conflicts of interest? *In* 'Proceedings of the 14th Australian Weeds Conference', Eds B.M Sindel and S.B. Johnson, pp. 42-48 (Weed Society of New South Wales, Sydney).

Walton, C.S. (2001). Implementation of a permitted list approach to plant introductions. *In* 'Weed Risk Assessment', Eds R.H. Groves, F.D. Panetta and J.G. Virtue (CSIRO Publishing, Collingwood, Victoria).

WTO (1994) *Agreement on the Application of Sanitary and Phytosanitary Measures*.

WWF (2003) Australia submission to the Australian Senate Environment, Communications, Information Technology and the Arts References Committee Inquiry into the regulation, control and management of invasive species and the Environment Protection and Biodiversity Conservation Amendment (Invasive Species) Bill 2002.

Appendix 1

AQIS Plant Introduction Form

"Why have I been asked to fill in this form?"

AQIS regulates all plant material imported into Australia. Each year, AQIS receives a large number of applications to import various plant species from all over the world. Many of these species have been imported before and AQIS has developed import conditions to enable their safe introduction. These species and their import conditions are contained in the AQIS electronic quarantine database – ICON (www.aqis.gov.au/icon).

AQIS regulates plant imports by way of a permitted list, which was formally adopted on the 7th July 1998. When an importer submits an application to import propagative material (seed or nursery stock) of a species that is not contained in ICON (or is listed in ICON as "prohibited until assessed"), AQIS forwards this information to Plant Biosecurity who conducts an assessment of the species. Plant Biosecurity Australia develops appropriate import conditions before the species can be imported and released from quarantine.

The agreed pre-entry screening method for new plant imports is called the Weed Risk Assessment (WRA) system. The WRA system is used on all new plant imports whether they enter Australia as seeds, nursery stock or tissue culture and regardless of country of origin.

"How do I fill in the form?"

In most cases, you will need to complete a separate AQIS Plant Introduction Form for each species requiring assessment. However, where there are different species or varieties that are very similar, you may place them on the same form. Environment Australia as well as a wide range of client groups endorsed this system of assessment. The implementation of the WRA system is a component of the National Weed Strategy and was funded in part by monies arising from the Natural Heritage Trust.

"Why should I bother?"

If you have been asked to complete the AQIS Plant Introduction Form, you should note that it is in your best interests to fill in the form as accurately and completely as possible. AQIS receives many applications to import plant species that require assessment and this assessment represents a significant demand on AQIS's resources. Import applications accompanied by an AQIS Plant Introduction Form that is properly filled in can be assessed more quickly.

This form is used to gain information on the general growth characteristics of the species and also to determine whether the plant possesses certain attributes, which could increase the likelihood of it becoming a weed in Australia. Based on the assessment of the information provided, AQIS will either (a) permit the plant to be imported subject to certain conditions, (b) refuse permission for the plant to be imported, or (c) require further assessment of the species while in quarantine.

Plants that are already present in Australia, either widely distributed or commercially available in significant quantities in Australia, still require assessment, but the final result will take the occurrence in Australia into account.

The form consists of four parts - Sections A, B, C, and D. You must complete all four sections. Where you are required to complete forms for more than one species you may complete Section A (Applicant's Details) on just one form only.

Use the "Don't know" box as little as possible so that AQIS does not have to ask you to provide further information. Also, feel free to clarify or qualify your answers by writing comments anywhere on the form.

Finally, make sure all written answers and comments are printed **neatly** and **clearly**.

"Is there any other information that I should provide?"

Yes, references will help the speed of the assessment! As part of the assessment process, AQIS/Plant Biosecurity must verify the accuracy of your responses on the form. Information from independent sources that substantiates your responses will facilitate this and will reduce the assessment time accordingly.

Independent sources include papers from scientific journals, botanical textbooks and gardening books. Also of use would be information supplied by botanical gardens, CSIRO, departments of agriculture or universities etc. AQIS will also accept information from independent sources overseas such as foreign government authorities and universities. Information from these sources must be supplied on the official letterhead of the organisation concerned.

Remember - **the more information you supply**, the less research Plant Biosecurity must do and **the shorter the assessment time**.

"What do I do with the completed form?"

Completed form and additional information should be sent to:

Plant Programs Section
Animal and Plant Programs Branch
AQIS
GPO Box 858
CANBERRA ACT 2601

or Fax: 02 6272 3745

AQIS will then advise you of the outcome of the assessment.

AQIS New Plant Introduction Form

Section A

Applicant's Details

A1. Applicant's Name: .....

A2. Company/Organisation: .....

A3. Telephone Number: .....

A4. Fax Number: .....

A5. Postal Address: .....

.....

.....

.....

A6. Seizure Number: .....…
(On accompanying letter if applicable)

Section B

B1. Genus: .....

B2. Species: .....

B3. Common Name(s): .....

B4. Family: .....

B5. Variety/Cultivar: .....

B6. Are there other varieties or cultivars, how many:
.....

B7. What plant form(s) do you wish to import?
(Tick more than one, if applicable)

- ☐ seeds
- ☐ tissue cultures
- ☐ whole plants, cuttings, bulbs etc

B8. What countries do you wish to import the plant from?
.....
.....

.....
.....

B9. Is the plant present in Australia? ☐ Yes (Go to B 10) ☐ No (Go to Section C) ☐ Don't know (Go to Section C)

B10. Is the plant native to Australia? ☐ Yes (Go to Section C) ☐ No (Go to B11) ☐ Don't know (Go to B11)

B11. Is the plant deliberately grown in Australia? ☐ Yes (Go to B11) ☐ No (Go to B13) ☐ Don't know (Go to B13)

B12. For what purpose(s) is the plant grown in Australia? (Tick more than one, if applicable)

☐ indoor ornamental
☐ outdoor ornamental
☐ fruit/vegetable crop
☐ medicinal/homeopathic
☐ botanical\collector specimen (Go to B13)
☐ land reclamation
☐ pasture
☐ animal feed
☐ other (please specify) .....

B13. What is the plant's distribution in Australia?

.....

.....
(Go to B14)

B14. Is the plant commercially available in Australia? ☐ Yes (Go to B15) ☐ No (Go to Section C) ☐ Don't know (Go to Section C)

B15. What Australian suppliers is the plant available from?

Name:..... Tel:.....

Name:..... Tel:.....

Name:..... Tel:.....

Name:..... Tel:.....

Section C

C1. Is the plant... (Tick more than one, if applicable)
☐ annual ☐ biennial ☐ perennial
☐ erect ☐ prostrate ☐ climbing

C2. To do what dimensions does the plant grow?.....

C3. Does the plant produce... (Leave blank if none apply)
☐ bulbs ☐ corms ☐ stolons
☐ tubers ☐ rhizomes ☐ thorns

C4. Is the plant a.. (Tick more than one, if applicable)
☐ tree ☐ vine ☐ palm
☐ shrub ☐ creeper ☐ fern
☐ herb ☐ grass ☐ sedge
☐ succulent ☐ bamboo ☐ epiphyte
☐ cactus ☐ aquatic ☐ legume (nitrogen fixer)
☐ woody ☐ herb ☐ carnivorous plant

C5. Does the plant naturally form new plants from vegetative fragments (rhizomes, suckers, stolons etc)?
☐ Yes ☐ No ☐ Don't know

C6. How are the propagules (seed, seed pods, fruit, viable vegetative fragments) likely to be dispersed? (Tick more than one, if applicable)

☐ wind
☐ water
☐ insects
☐ by being eaten by birds
☐ by being eaten by animals
☐ on the bodies of birds
☐ on the bodies of animal
☐ other (please specify)

C7. Does the plant grow in rivers, lakes or ponds?
☐ Yes ☐ No ☐ Don't know

If '**Yes**' is the plant a free-floating (surface submerged) aquatic or can it survive as one?
☐ Yes ☐ No ☐ Don't know

C8. What climate is the plant adapted to?

☐ tropical ☐ cold temperate

☐ sub-tropical ☐ arid

☐ warm temperate (Mediterranean) ☐ other (please specify).....

C9. What is the native habitat of the plant?

☐ rainforest ☐ grassland ☐ swamp, marshland

☐ wet temperate forest ☐ coastal ☐ alpine

☐ dry temperate forest ☐ river, lake, pond ☐ other (please specify)

C10. What countries and/or geographical regions is the plant native to?

....

....

C11. Has the plant had a history of repeated introductions outside its native region? ☐ Yes ☐ No ☐ Don't know

If you ticked "**Yes**", list the countries the plant has been introduced to.

.....

C12. Is the plant native to or naturalised in areas with rainfall of less than 25 mm in the driest quarter of the year? ☐ Yes ☐ No ☐ Don't know

C13. Has the plant been effectively controlled using herbicides in situations where the plant has become undesirable? ☐ Yes ☐ No ☐ Don't know

C14. Does the plant suppress the growth of other plants? ☐ Yes ☐ No ☐ Don't know

C15. Is the plant parasitic on other plants? ☐ Yes ☐ No ☐ Don't know

If you ticked "**Yes**", list the species the plant is parasitic on.....

C16. Has the plant species or any of its races or sub-species become weeds in...

- ☐ gardens?
- ☐ disturbed ground (e.g. roadsides)?
- ☐ crops? (please specify).....
- ☐ pastures?
- ☐ terrestrial ecosystems?
- ☐ aquatic ecosystems?
- ☐ other? (please specify).....

C17. Is the plant affected by or host to any pests or diseases?

☐ Yes ☐ No ☐ Don't know

If you ticked "**Yes**", list the pests and diseases.....

.....

C18. Are there any factors (predators, diseases, climatic conditions etc) in the plant's native habitat that substantially reduce its reproductive capacity?

☐ Yes ☐ No ☐ Don't know

If you ticked "**Yes**", list the factors.
.....

C19. Does the plant have any effective natural enemies (predators, pests, diseases) in Australia?

☐ Yes ☐ No ☐ Don't know

If you ticked "**Yes**", list the natural enemies.
.....

C20. Is the plant tolerant of shade at any stage of its life-cycle?

☐ Yes ☐ No ☐ Don't know

C21. Is the plant tolerant of infertile soils?

☐ Yes ☐ No ☐ Don't know

C22. Does the plant have a climbing or smothering growth habit?

☐ Yes ☐ No ☐ Don't know

C23. Does the plant form dense thickets or colonies?

☐ Yes ☐ No ☐ Don't know

C24. Does the growth habit of the plant create a fire hazard in natural ecosystems?
☐ Yes ☐ No ☐ Don't know

C25. Does the plant produce viable seed?
☐ Yes ☐ No ☐ Don't know

If you ticked "**Yes**", can the plant produce more than 2000 viable seeds per square metre under natural conditions?

☐ Yes ☐ No ☐ Don't know

C26. Does the plant hybridise with other species without assistance under natural conditions?
☐ Yes ☐ No ☐ Don't know

C27. Is the plant able to produce viable seed without cross-pollination?
☐ Yes ☐ No ☐ Don't know

If you ticked "**No**", what is the pollinating agent?

☐ wind

☐ insects (please specify).....

☐ birds (please specify).....

☐ animals (please specify).....

☐ other (please specify).....

C28. What is the minimum time from germination to the production of viable seed or the time taken for a vegetatively propagated plant to duplicate itself? .....

C29. Are the propagules(seed, seed pods, fruit, viable vegetative fragments) buoyant?
☐ Yes ☐ No ☐ Don't know

C30. Do the propagules remain viable after being eaten and excreted by animals and/or birds?
☐ Yes ☐ No ☐ Don't know

C31. Do more than 1% of the propagules remain viable after more than 1 year in the soil? ☐ Yes ☐ No ☐ Don't know

C32. Has the plant been selected for any specific traits? (Tick more than one, if applicable)

- ☐ herbicide tolerance
- ☐ pest tolerance/resistance (virus, bacteria, fungus, nematode, insects)
- ☐ production of toxic substances (poisons, pesticides)
- ☐ environmental enhancement (drought tolerant, salt resistant, heavy metal tolerant, hard seededness, growth in infertile soils)
- ☐ enhanced growth characters (increased fruiting, increasing seeding, faster growth rate)
- ☐ other.....

If you ticked a box please describe the selection: .....

.....

C33. Has the plant been registered with Plant Breeders Rights? ☐ Yes ☐ No ☐ Don't know

Section D

Applicant's Declaration

The information that I have provided on this form is correct to the best of my knowledge.

.....
(Signature of applicant)

.....
(Full name of applicant)

...../...../……
(Date)

Please return the completed form to:

Plant Programs Section
Animal and Plant Programs Branch
AQIS
GPO Box 858
CANBERRA ACT 2601

OR FAX: 02 6272 3745

Don't forget to attach additional information from independent sources.

APPENDIX 2

Determining the weed potential of new plant introductions to Australia

A report on the development of a Weed Risk Assessment System commissioned by the Australian Weeds Committee and the Plant Industries Committee

P. C. Pheloung
Agriculture Protection Board, Western Australia

July 1995
Minor revision September 1995

Executive summary

1. A workshop and report in 1994 gave guidelines for a three tiered screening system to assess weed potential of plant introductions. Plant species which pass the **first tier** (they are not present on prohibited or allowed lists of species, and are potential quarantine pests) are to be assessed before entry by a formal Weed Risk Assessment (**WRA**) system, which is the **second tier** (page 71).
2. Further testing and development was carried out, with assistance from workshop participants representing all states, to demonstrate that the WRA system could satisfactorily meet requirements (page 74).
3. In this system, answers are sought for questions on historical, biogeographical and biological/ecological details of the candidate (page 77).
4. The score generated by the procedure determines which of three recommendations, **reject**, **evaluate** or **accept**, will result (page 77).
5. *Evaluation* may simply require re-running the system with more information, economic cost/benefit analysis or activation of the **third tier** which is temporary clearance to import for post-entry evaluation (page 75).
6. A routine WRA should take 1-2 days per species to complete, if library and computer resources are on hand, and less if the importer provides the required documentation. The volume of assessments will progressively decrease as the more common occurrences are dealt with and assigned to the schedules of prohibited and approved plant species (page 79).
7. The WRA system was tested by analysis of its performance for 370 plant species, representing weeds from agricultural, environmental and other sectors, and useful plants. The system was judged on its ability to correctly *reject* weeds, *accept* non-weeds and generate a low proportion of species requiring *evaluation*. The performance of the system was compared to that of two simpler systems (page 80).
8. In the optimised WRA system, all serious weeds, and most minor weeds, were rejected or required *evaluation* while only 7% of non-weeds were rejected. Less than 30% of the species required *evaluation* (page 83).
9. Although simpler systems were effective, the WRA system performed best. The simpler systems produced too many *evaluate* recommendations or rejected too many non-weeds. They were constrained by their lack of flexibility (page 83).
10. The WRA system has some capacity to detect environmental weeds and identify them as such (page 88).
11. The ability of the WRA system to make reliable recommendations has a sound quantitative basis, and the mechanism is transparent. These features are basic requirements for establishing phytosanitary conditions in accordance with the GATT SPS agreement (page 89).

Recommendations

1. That the WRA system be adopted for pre-entry assessment of weed potential of new plant introductions as the second part of a three tiered system.
2. That implementation of the WRA system be consistent with the requirements of AQIS and ANCA, in consultation with P Pheloung.
3. That more specific details of the protocol for evaluate recommendations, such as cost/benefit economic considerations and post-entry protocols to study weed risk, be established.

Structure of report.

1. Part I: The main report. ☐
2. Part II: The Weed Risk Assessment manual. ☐
3. Part III: An attachment of appendices containing the complete dataset. ☐
4. A computer disk containing the computer based system (PC or Mac format, Microsoft Excel 5 is required to run the system). ☐

Any part not included can be obtained from Paul Pheloung, Agriculture Protection Board, 3 Baron-Hay Court, South Perth WA 6151. (09) 368 3679.

Table of contents

Acknowledgments

This report is the culmination of a largely collaborative effort to gather and process information on several hundred plant species. The individual contributors, and their contributions, are acknowledged in Table 2.

The Australian Quarantine and Inspection Service (AQIS) provided funding for resources and technical assistance.

PART I

Background/ Introduction

Current systems for screening plant introductions

The Australian Quarantine and Inspection Service (AQIS) is the national organisation responsible for detecting and approving the introduction of plant species. In the past, AQIS has managed this by reference to schedules of prohibited species. The list of proscribed species has been under revision and a much expanded draft list (quarantine schedule 86P) is under consideration. There is a concern that, as was the case with *Kochia scoparia*, plants which are not identified as weeds, and therefore are not on such a list, will be allowed entry.

AQIS also has the power to intercept and hold indefinitely any species that it feels could become an economic pest in Australia, and has not already become widely established (see definitions, page 75). AQIS must base these decisions on expert judgement. Because of the volume of plant imports, it has become apparent that a well defined and reasonably simple system or protocol is necessary for estimating the risk of an introduction becoming a weed pest.

AQIS has used a simple point scoring system (

Table 1) to assist in this task. The score is translated into one of three recommendations:

1. *Accept*
2. *Reject*
3. *Evaluate* (examine further)

An alternative, proposed by Panetta (1993), uses a decision tree approach to generate these recommendations (Figure 1). The structure of the flow chart clearly illustrates the categorising of plant attributes into:

1. documented distribution
2. documented weediness
3. noxious traits
4. biological traits relating to reproduction and dispersal.

Both systems emphasise the overriding influence of documented weediness, coupled with the presence of suitable habitats in Australia. They will be referred to as the AQIS system and the Panetta system in the remainder of this report.

1994 Workshop and Report

In response to an initiative of the National Weeds Strategy, the Australian Weeds Committee (AWC) commissioned a workshop in 1994 (Screening Plants for Weediness: a procedure for assessing species proposed for importation into Australia). The purpose of the workshop was:

To review and agree on transparent administrative procedures for plant species introductions aimed to minimise the introduction of plants that will, on balance, be detrimental to Australia.

The workshop report (Panetta *et al.* 1994) gave guidelines for a three tiered plant screening process, to be applied progressively as required:

1. Identification of the species and its Australian distribution, with reference to current lists of *prohibited* and *permitted* species.
2. If the species is not listed and is not established in Australia, apply a pre-entry assessment procedure to determine the risk of the species becoming a weed Australia: the possible recommendations are *accept*, *reject* or *evaluate*. Rejected or accepted species are then added to the *prohibited* or *permitted* list. *Evaluate* recommendations may be resolved at this stage by repeating pre-entry assessment with more information, or an econmic cost benefit analysis.
3. If an *accept* or *reject* recommendation cannot obtained from the second tier, and the importer wishes to proceed, subject the species to post-entry evaluation so that, ultimately, the species can be placed on a *prohibited* or *permitted* list.

A computer based system was devised to identify plant species that are potential quarantine pests. This system was built on the principles embodied in the AQIS and Panetta systems. Operation of the system was demonstrated at the workshop, along with an analysis of its performance in rating 50 species varying in weediness.

The computer based system deals specifically with the second tier: pre-entry assessment of weed potential and will be referred to as the Weed Risk Assessment system (WRA).

Table 1. Scoring system currently used by AQIS for decision-making on the importation of plants (after Hazard 1988). Referred to in this report as the AQIS system.

	Criterion	Points
1.	Is the species a free-floating (surface or submerged) aquatic or can it survive, grow and reproduce as a free-floating aquatic?	20[A]
2.	Does the species have a history of being a major weed elsewhere in similar habitats (remember Australia is a big country of diverse habitats)?	20
3.	Does the species have a close relative of similar biology with a history of weediness in similar habitats?	10
4.	Are the plants spiny?	10
5.	Does the plant have spiny diaspores (ie. burrs)?	10
6.	Are the plants harmful to humans and/or animals?	8
7.	Do the plants produce stolons?	5
8.	Do the plants have other forms of vegetative reproduction?	8
9.	Are the diaspores wind-dispersed?	8
10.	Are the diaspores dispersed by animals and/or machinery?	8
11.	Are the diaspores dispersed by water?	5
12.	Are the diaspores dispersed by birds?	5

[A] Scores totalling $\geq$20, between 12 and 19, or <12 indicate grounds for rejection, further examination or acceptance, respectively.

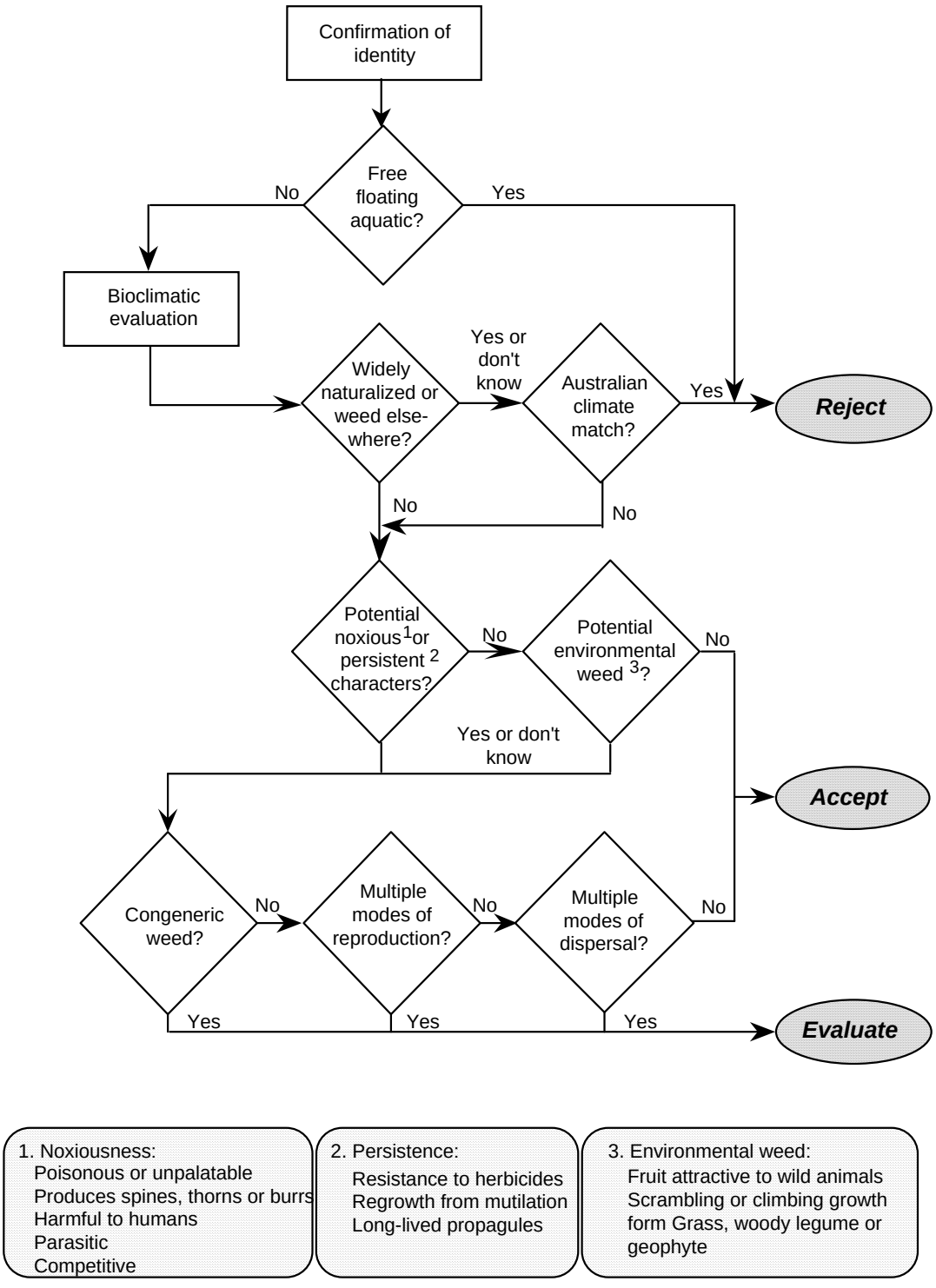


Figure 1. A screening system for proposed plant introductions (modified after Panetta 1993).

Guidelines followed during development of the WRA system

Further testing and development was carried out, with assistance from workshop participants representing all states, to demonstrate that the WRA system could satisfactorily meet requirements.

This work was endorsed at the 1994 workshop and, subsequently, the Plant Industries Committee (PIC) resolved that testing and development of the WRA system be completed and a report prepared, by July 1995. AQIS provided funding to facilitate the process.

An acceptable WRA system must meet a number of requirements that were specified at the workshop, and by PIC:

1. The system should be calibrated and validated against a large number of species, already present in Australia, representing the full spectrum of species likely to be encountered as imports. A number of workshop participants volunteered their services to assist in this process.
2. It must be shown that the screening procedure is reasonably effective at discriminating between weeds and non-weeds.
3. The dataset resulting from this process should be used to adjust the scoring system such that the majority of weeds are not accepted, non-weeds are not rejected and the proportion requiring *evaluation* is kept as small as possible.
4. International trade agreements require that prohibited species should fit the definition of a quarantine pest (see box). The assessment procedure should be fully transparent and based on sound scientific principles so that Australia cannot be accused of applying unjustified non-tariff trade barriers.
5. Resources needed to operate the system should be realistic - the cost in time and money to the importer and the administering body (AQIS) should be as low as possible.
6. The system should be capable of identifying environmental weeds (weeds of conservation or bushland weeds) and identifying them as such. This could be necessary since such weeds may not fit the definition of a quarantine pest as it is commonly interpreted (see box). These items could be referred to ANCA for further action.
7. In the majority of cases, the decision will be made for a species, but the system should be capable of dealing with species at the genus or subspecies level. Some allowance must be made for well-defined subspecies or varieties which have economic benefits and attributes that render them less weedy than other members of the species. For convenience, the term species is used in this report to refer to the more general concept.
8. The system should provide significant improvement over others currently in use.

International trade agreements (Anon 1992) require plants that are denied entry to a region to conform to the definition of a quarantine pest:

Pest:	Any species, strain or biotype of plant, animal or pathogenic agent, injurious to plants or plant products.
Quarantine Pest:	A pest of potential economic importance to an area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled.
Official	Established, authorised or performed by a national plant protection agency.
Control	Suppression, containment or eradication of pest populations.

Applying the tiers

The first tier of the screening system determines whether a plant requires WRA. Part of this is determining if the plant is a potential quarantine pest (see box on page 75). If a species is already widely distributed, then new introductions are unlikely to have any further effect, unless it can be clearly shown that the new introduction is significantly different genetically, and the difference has pest implications.

If the pest is present but not widely distributed, official control of the existing infestations is essential. Otherwise, quarantine serves no useful purpose. Regulatory organisations are expected to make rational and realistic judgements (Panetta and Scanlan 1995) about what species should be officially subject to official control. Prohibited entry of a plant should be based on such judgements.

The second tier is the WRA system, but a protocol for assessing the economic benefits of an introduction is necessary, in the event that WRA recommends *evaluate*.

Evaluation includes a number of options:

1. Repeat the WRA system, using updated information,
2. An economic cost/benefit analysis to justify the risk,
3. The third tier: post-entry evaluation in the form of field studies supervised by an expert panel to examine more directly weed potential (and verify potential benefits).

These steps are progressively more time consuming and costly, so the aim is to apply them sequentially and reach a decision to *accept* or *reject* (or simply terminate the process) as soon as possible.

The tiers correspond to the first two stages described in an FAO document on guidelines for Pest Risk Analysis (Anon 1995). The flow chart in Figure 2 shows how WRA fits into the overall protocol for screening plant introductions.

The FAO report cites the following factors as examples of economic importance:

1. Type of damage
2. Crop losses

3. Loss of export markets
4. Increases in control costs
5. Effects of ongoing Integrated Pest Management (IPM) programmes
6. Environmental damage
7. Capacity to act as a vector for other pests.

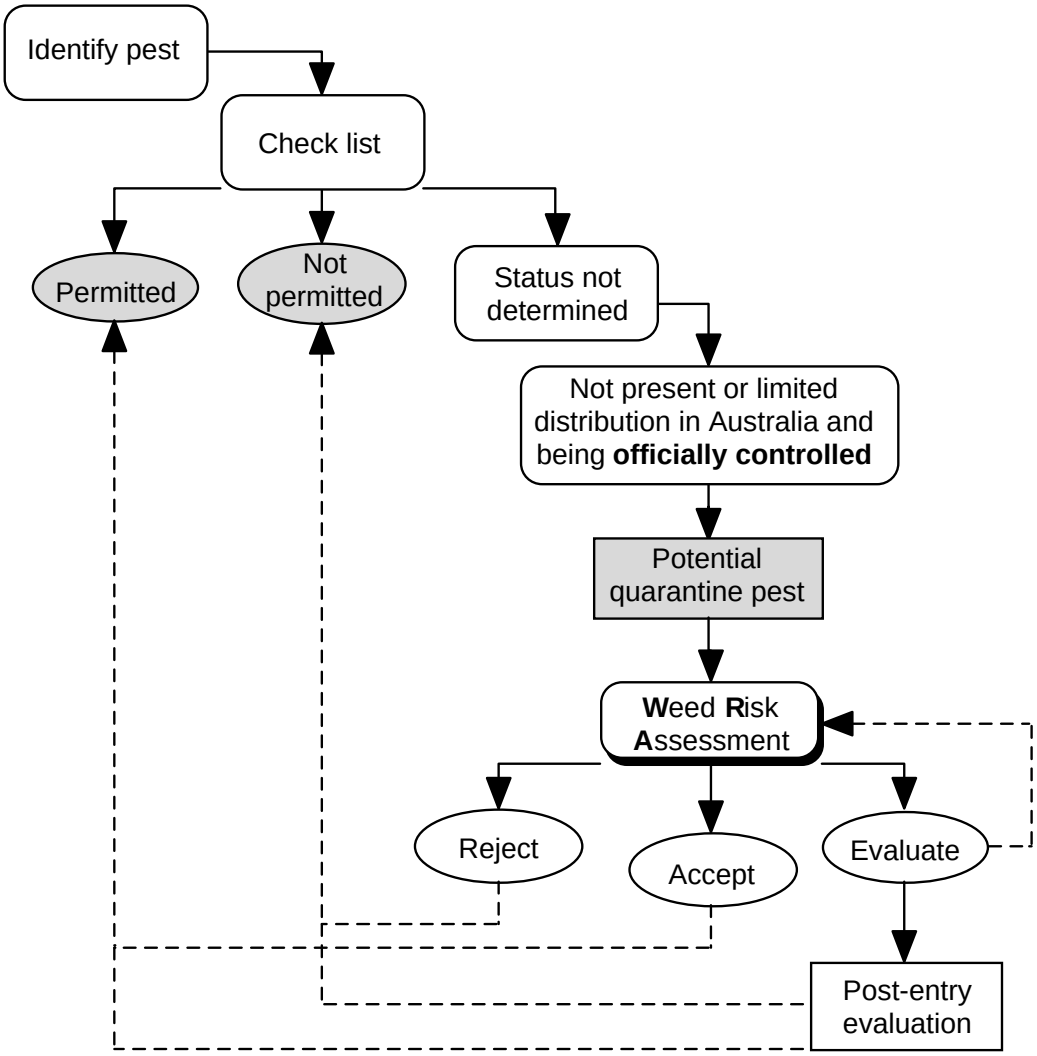


Figure 2 Flow chart for screening plant introductions.

The Weed Risk Assessment (WRA) System

Structure

Answers are sought for questions on historical, biogeographical and biological/ecological details of the candidate (Part II Form A).

These answers are almost entirely in the form of *yes*, *no* or *don't know*, and are used to produce a score related to weediness. The complete system is described in Part II and the question sheet is given in Part II, form A.

The score generated by the procedure is used to determine which of three recommendations, *reject*, *evaluate* or *accept* (the latter allowing clearance to import and release), will result.

The WRA system is set up to run on a computer but can be operated on paper. A full description is given in Part II. It is incorporated into a computer based environment to accelerate the process, help enforce objectivity, and automatically maintain a database of assessed species. A complete set of responses for each species is stored in a database and can be reviewed at any time, and reassessed if details of the scoring system are changed.

The scoring system

The WRA system generates a numerical score based on 49 questions that is positively correlated to weediness (Part II, Forms A and B). It is, in essence, an expanded form of the system currently used by AQIS (Table 1). However, in addition to being more comprehensive, it introduces added flexibility: there is no requirement to answer all questions, and positive (non-weedy) traits are taken into account.

The system attempts to take account of all the information that would be utilised by the AQIS and Panetta systems, with expansion of some broader questions from these systems into several smaller steps.

A minimum number of questions must be answered from each of the three main sections:

1. **Biogeography:** the documented distribution, climate preferences and weediness in other parts of the world. The distribution and climate preferences should be used to predict a potential distribution in Australia using available prediction systems. The default, if this is not done, is to assume the species will readily grow unaided in Australia (Part 2, questions 1-3).
2. **Undesirable attributes:** these are the noxious or invasive characters comparable to the second tier in Panetta's system (Figure 1; Part 2, questions 4.1-4.12).
3. **Biology/ecology:** these are the attributes that contribute to the capacity of the species to reproduce, spread and persist (Part 2, questions 5-8).

In most cases, one point is added for a weedy attribute and one point is deducted for a non-weedy attribute. Grading the relative importance of the various questions was avoided as being too subjective. Assessment of potential distribution, based on climate matching, is used to weight the responses to four questions on weed status in other parts of the world: a good climate match increases the value of a 'Yes' response to these questions.

Converting the score to a recommendation

The three possible recommendations (*accept*, *evaluate* or *reject*) are determined by two critical score settings. The lower critical score separates acceptable species from those requiring *evaluation* and the higher critical score separates species requiring *evaluation* from those that should be rejected. The positioning of these critical scores was determined by a calibration process using information on weeds, non-weeds and other economically important plants that are present in Australia (Section 0).

An attempt was made to classify the questions according to their relevance in identifying attributes associated with agricultural, environmental and nuisance weeds (Part II, Form A). Nearly half of the questions (22) were classified in this way, but the remainder of the questions were considered relevant to all sectors. In addition to an overall score, scores derived from questions of agricultural and environmental relevance are also generated to give an indication of the sectors likely to be affected. For example, if the agricultural score is negative, but the environmental score is positive and the overall result is *reject*, then the species is probably a potential environmental weed only.

The system described is best suited to intentional imports of plant propagules. Another important category is weed contaminants in imports of approved seed varieties or plant material not intended for sowing. AQIS is currently reviewing its policy on contaminants. The WRA system could be the basis of such a system, but may need to have different ways of interpreting the score, based on a measure of the risk that the pest will reach a favourable site for establishment.

Rationale for questions

The selection of questions was based on the accumulated wisdom of ecological and weed research and was discussed in detail in the workshop report (Panetta *et al.* 1994).

It is widely accepted that a weed in some part of the world has a good chance of being weedy in other areas with similar environmental conditions. This consideration has the greatest influence on the recommendation. It is also possible for a species that has not been particularly weedy to become so in a new situation. A number Australian noxious weeds (Parsons and Cuthbertson 1992) are not documented weeds elsewhere. The remainder of the system attempts to identify such candidates by identifying biological attributes.

The system seeks to produce recommendations according to the principles embodied in Panetta's system:

1. Weeds from other parts of the world should not be allowed entry if the climate in Australia is similar,
2. Otherwise, species with biological attributes suggestive of invasive plants or weeds should be subjected to *evaluation.*
3. Otherwise, species should be accepted.

In view of the difficulty in definitively measuring weed potential, the precautionary principle should be applied to all decisions such that, if information important to the determination of weed potential is not available, the species should not be accepted.

Information required to operate the WRA system

A routine WRA should take 1-2 days per species to complete, if library and computer resources are on hand, and less if the importer provides the required documentation. The volume of assessments will progressively decrease as the more common occurrences are dealt with and assigned to the schedules of prohibited and approved species.

Australian assessors are not likely to have detailed knowledge of new plant introductions. Assessment must be based on information obtained from the literature. Primary sources would be Holm *et al.* (1979) for a quick summary of weed status throughout the world (mainly weeds of agriculture), Hnatiuk (1990) for presence of particular species in Australia, and world floras for native and naturalised distributions (to determine climate preferences).

Electronic resources for information acquisition are becoming increasingly accessible and useful. Abstracting systems available on compact disk, such as CAB and Biological Abstracts, provide a comprehensive, up to date synopsis of current literature. Other weed databases are coming online, particularly the World Weed Database evolving from the work of Holm *et al.* (1979). These electronic forums provide a means of rapidly obtaining relevant unpublished or obscure information, particularly on species that have become weeds in natural ecosystems. It is also necessary to have access to the most up to date information on the presence and distribution in Australia.

The worldwide distribution can be used to determine the degree and extent of similar climates in Australia. At least two programs, (*Climex*, CSIRO Division of Entomology, Qld; *Climate*, Department of Agriculture, WA) can perform this task without difficulty. If a formal analysis is not done, a good match should be assumed unless the natural distribution of the species clearly does not coincide with Australian climates; this would probably only include cold, high latitude regions. Simplified maps of the 20 or so major climatic zones of the world can be found in good atlases. Such maps can be used to provide answers to the remaining climate related questions.

To facilitate the process and reduce costs, the importer can provide much of the necessary information with substantiation as required. Since assessment should precede the arrival of the species at the barrier, an accurate and unambiguous identification of the plant is essential.

Information on the species likely to be encountered will be variable and often sparse. In recognition of this, the questions attempt to cover a wide range of attributes with no requirement that any particular question be answered (the climate section will default to the worst case if not answered). Nevertheless, a minimum number of questions from each section must be answered or the system will indicate that more information is required.

It has been suggested that a fully answered set of questions should always result in *accept* or *reject*. This is not the case, or the intention. For many species, there will be uncertainty that cannot be resolved without direct evaluation under Australian environmental conditions.

Calibrating and testing the WRA system

The WRA system was tested by analysis of its performance for 370 plant species, representing weeds from agricultural, environmental and other sectors, and useful species. The system was judged on its ability to correctly *reject* weeds, *accept* non-weeds and generate a low proportion of species requiring *evaluation*. The performance of the system was compared to that of the AQIS and Panetta systems.

The modifications and tests were based on comments and input from workshop participants and others. A survey of scientists was done to define the weed status of each species. The species were given a rank from 0 to 2, which was used to classify them as *non-weeds*, *minor weeds* and *serious weeds*, respectively. This classification is subjective and may contain errors but should provide a good basis for measuring the performance of the WRA system.

The assessed species

The WRA system, as it was presented at the June 1994 workshop, was circulated to a number of participants who had volunteered to assist. The volunteers were professional scientists in the fields of ecology, botany and agronomy. They were asked to use the system to assess the weed potential of species they were familiar with, ranging from non-weedy beneficial species to serious weeds. All species that have a noxious status in Australia were assessed using the information provided in Parsons and Cuthbertson (1992). Contributors to the list of assessed species are given in Table 2 and the complete list of assessments is given in Part III.

Assessors were asked to treat each species as if it had not yet arrived in Australia. Species that are serious weeds in Australia, for example, were to be assessed purely on their weed status outside Australia.

At least one contributor did not rigidly adhere to ignoring Australian weed status in the course of making assessments. Consequently, responses to the 'Weed Elsewhere' section (Section 0, Form A) were carefully checked for serious inconsistencies and altered in such cases. Holm *et al.* (1979) and Parsons and Cuthbertson (1992) were the authorities used.

Some attempt was made to examine the results for

1. obvious errors
2. big differences where more than one assessment was made of the same species
3. aberrant recommendations

The responses of the original assessors were used in all but the clearest cases of an inconsistent response.

Modifications based on expert comment

Several of the workshop participants, and others, provided critical comment on the system (Table 2). These comments were invaluable in modifying the system. They helped to highlight areas of ambiguity or vagueness in the wording of the questions. The analysis of system performance is based on the modified version. An appraisal of the comments provided, is given in Part III.

Table 2 Contributors to development of the Weed Risk Assessment System

Contributor		species assessed		Critical
		WRA	Survey	comment
Bryan Hacker & Bruce Pengelly	CSIRO (tropical pastures) Qld	5	102	v
Craig Walton & Darren Phillips	AQIS ACT	-	117	v
Dane Panetta	Alan Fletcher Research Station Qld	-	353	v
David Cooke	Animal and Plant Control Commission SA	113	219	v
Jon Dodd	Agriculture Protection Board WA	-	289	v
Mark Boersma	Dept. of Primary Industries and Fisheries Tas	25	137	v
Mark Lonsdale	CSIRO (entomology) NT	187	-	v
Michael Mulvaney	Australian Heritage Commission ACT	31	274	v
Roger Cousens	Dept. of Agriculture WA	-	263	v
Richard Carter	Animal and Plant Control Commission SA	-	233	
Rod Randall & Paul Pheloung	Agriculture Protection Board WA	301	128	v
Stephen Halloy	Invermay Agricultural Centre NZ	-	-	v
Surrey Jacobs	National Herbarium NSW	-	348	v

In some cases, a modification would require that the response to a question be reconsidered. To the extent possible, the responses to questions were modified to account for rewording and other alterations. Ideally, the program would need to be recirculated so that contributors could reassess their species based on the modifications. This was not feasible within the available time so the validation of the system is based largely on responses supplied for the system as originally circulated.

A number of important suggestions, which were not adopted in the modifications, deserve comment here:

- *Grasses should not be grouped together as guilty of weediness by association*

  In fact, this is one of the more reliable indicators of weed risk since such a large proportion of the grass family is weedy. The risk must be offset against the potential economic benefits that arise from the same attributes that are linked to invasiveness (eg. readily established, spreading and self-sustaining). These considerations are more appropriate at the *evaluate* stage, if the species falls into this category.

- *A different set of questions should be asked, based of the vulnerable sector (rangeland, cropping, horticultural, ornamental etc).*

  The pre-entry assessment should function as a simple generic process that considers weed potential without regard to the sector at risk or the economic benefits. It is expected that all species for which the weed potential is low or uncertain will be subject to *evaluation*, if not accepted. The intended use of the plant can be considered as part of the process of *evaluation*.

Classifying the assessed species

Twelve scientists, some of whom also provided assessments and comments, responded to a request to complete a survey composed of all the species assessed by the WRA system (Table 2). Contributors were asked to classify each plant for weediness and usefulness on a 0 - 2 scale. They were asked only to give responses for species that they were familiar with and to take account of the Australian experience. The contributors were also asked to classify weeds according to the sector affected (agriculture, environment, etc.). The complete results of the survey are given in Part III.

The survey was intended to provide a reference measure of the weed status, in Australia, for the assessed species. The weed status of each plant is derived from the collective opinion of one to twelve experts. The analyses are based on species for which at least two opinions were provided. The results of the survey are summarised in (Table 3). Although the majority of species (81%) are perceived as weeds in some context, less than half are considered serious weeds. A good sample of non-weeds and useful species, some of which are also considered to be weeds, were included. Weeds from all sectors (agriculture, environment, etc.) were well represented.

Table 3 Summary of survey results for species which were scored by at least two respondents

	number	% of all species
Species surveyed	370	
Weeds and useful species		
Serious Weeds	160	43
Minor Weeds	141	38
Non-weeds	69	19
Very useful	78	21
Moderately useful	154	42
Not useful	138	37
Useful non-weeds	67	18
Useful weeds	165	45
Distribution of weeds according to category		
Agricultural	138	38
Environmental	198	54
Horticultural	24	7
Garden	31	9
Service areas	115	31

Performance

Critical values

In the optimised WRA system, all serious weeds, and most minor weeds, were rejected or required *evaluation* while only 7% of non-weeds were rejected. Less than 30% of the species required *evaluation*.

The frequency distributions of WRA scores for each of the survey classifications are shown in Figure 3. Figure 4 presents the same data as cumulative frequency and also shows how environmental or agricultural weeds are partitioned by the system. This data was used to investigate the effect of different pairs of critical values on the distribution of WRA recommendations.

The range of scores for non-weeds overlaps the range for serious weeds so it is impossible to define any set of critical values that reject all serious weeds while accepting all non-weeds. However, it is possible to ensure that none of the serious weeds are accepted by setting the maximum *accept* score at 0. Similarly, less than 10% of non-weeds will be rejected if the *reject* score is greater than 6. This would mean that 29% of the species assessed in this study would fall between these extremes and require *evaluation*. Lowering the minimum reject score to 6 would reduce this proportion to 22% but increase the proportion of rejected non-weeds to 15%, which is less desirable, since some of these are regarded as useful (Figure 4). Consequently, the critical scores, of 0 and 7, were used convert the WRA scores into the recommendations, *accept*, *evaluate* and *reject*.

The results are summarised in Table 4 and a complete list of the species, partitioned into WRA recommendations and survey classifications, is given in Table 9. A number of useful species, particularly grasses, are rejected. In many of the cases, this is because few or no questions were answered in the last two sections of the WRA system. It is likely that specific information on the dispersal and persistence properties of these species could lower the score into the *evaluate* range.

Comparing the systems

The species were also scored using the AQIS and Panetta systems. Although these systems were effective, the WRA system performed best. The simpler systems produced too many *evaluate* recommendations or rejected too many non-weeds. They were constrained by their lack of flexibility.

For many of the species, information required by the AQIS or Panetta systems was not available. The precautionary principle was applied in such cases for the AQIS system: if a question was not answered then the result is *evaluate*. In the Panetta system, the path taken where an answer was not supplied is shown in Figure 1. Lack of information has meant that the Panetta and AQIS systems accepted fewer species than the WRA system (26, 36 and 73 species, respectively).

In all systems, *accept* recommendations were more likely as plant usefulness increased (Figure 5). The systems performed similarly in rejecting at least 80% of the species not considered useful. However, the proportion of useful species allowed entry was highest for

A comparison of system recommendations is shown in Figure 5. In this figure, the partitioning of assessment recommendations is shown for each survey classification. All systems were effective in rejecting most (85-91%) of the serious weeds. The Panetta system was most severe, rejecting about 26% of non-weeds and 75% of minor weeds. The WRA system was the least severe in dealing with non-weeds: nearly 60% were accepted and only 7% were rejected.

the WRA system (30%).

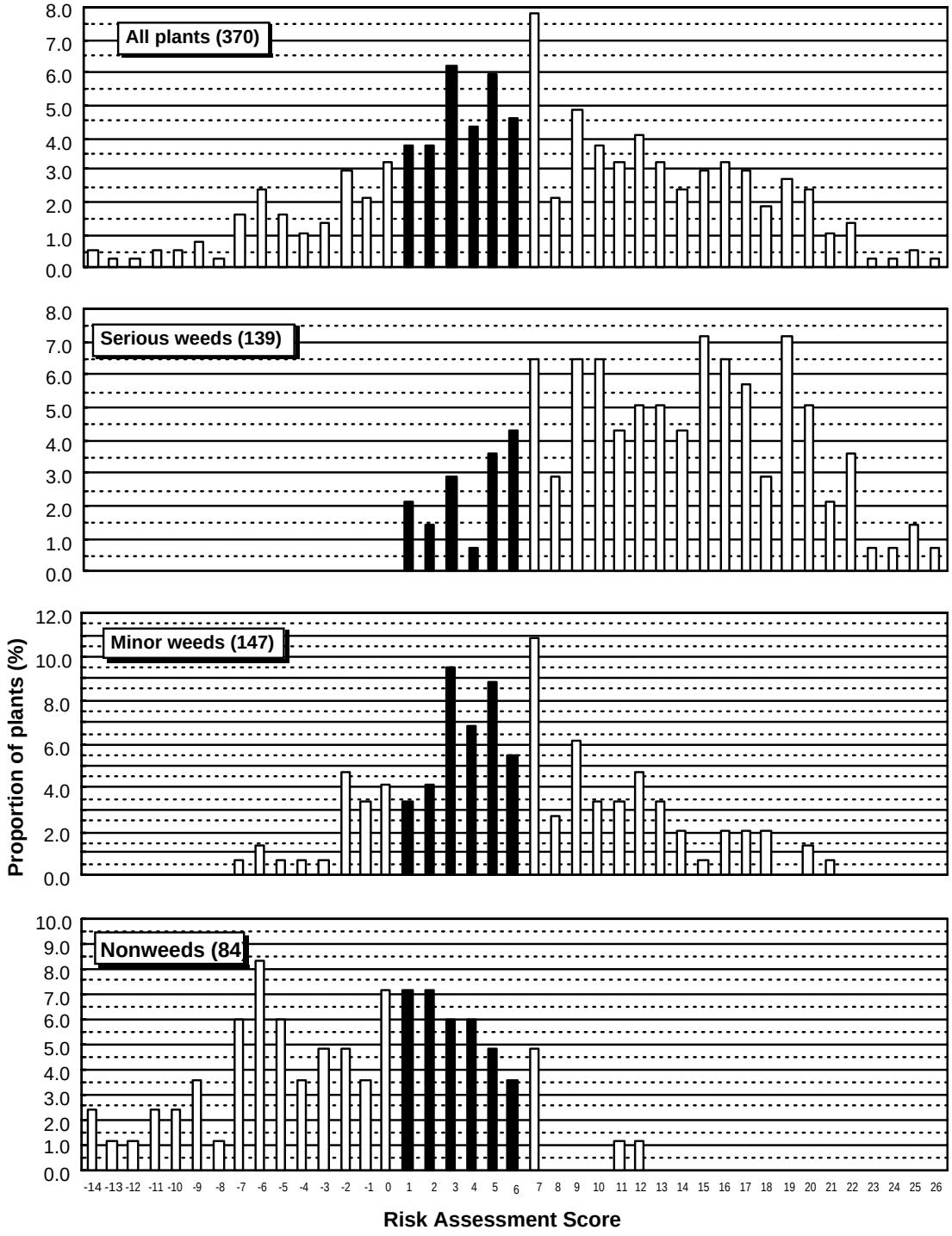


Figure 3 Frequency distributions for all assessed species and each of the survey weed classifications. Serious weeds were those which scored 2 in the survey, minor weeds scored 1 and non-weeds scored 0. This analysis was done for species graded by at least two respondents in the survey. The black columns refer to *evaluate* recommendations, bounded by critical WRA scores set at 0 and 6.

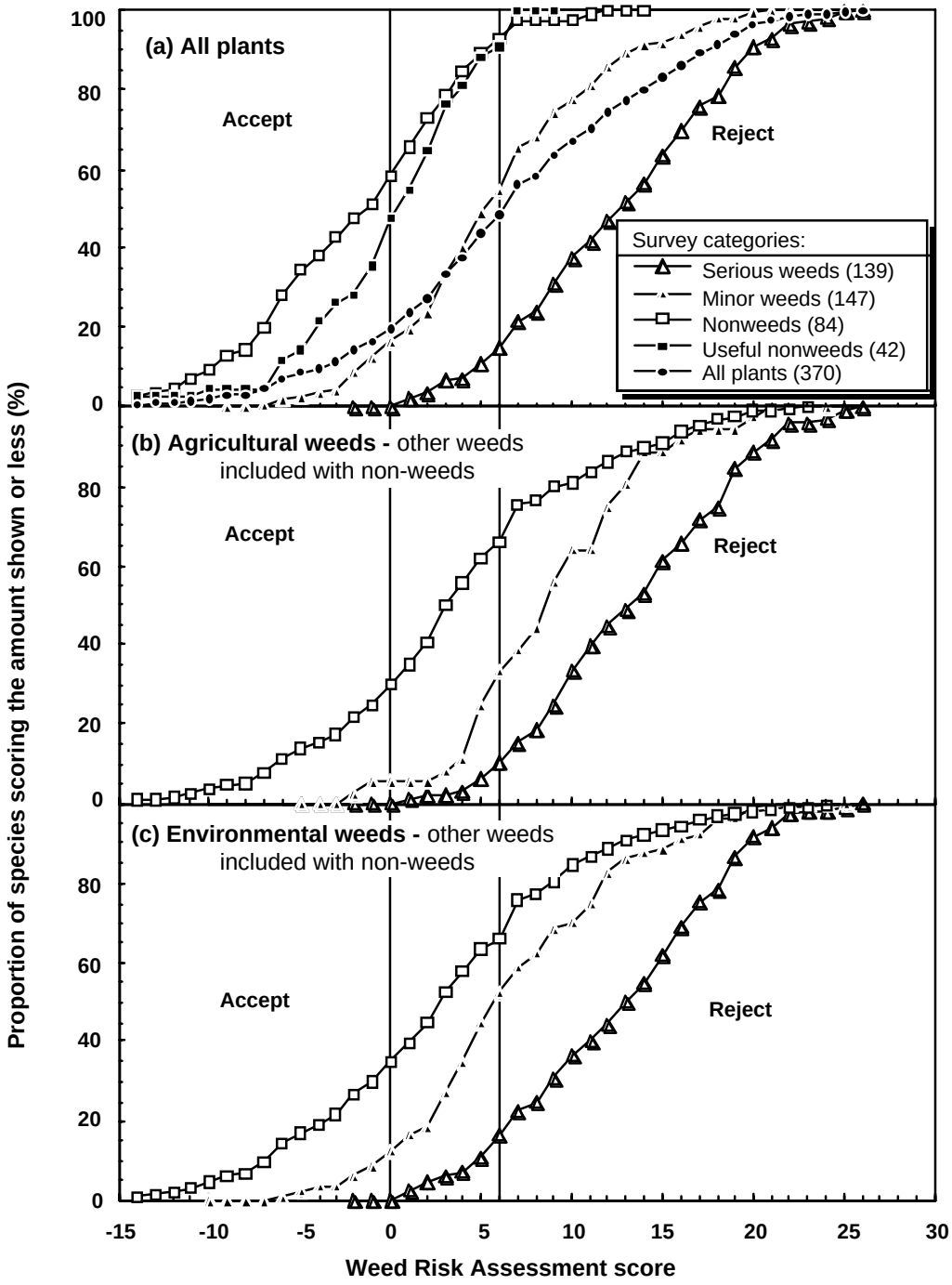


Figure 4 Cumulative frequency of species receiving a given WRA score or less for the survey classifications, as described in Figure 2. Useful species were those which scored 2 and were not considered weeds

Table 4 Distribution of recommendations for the three assessment systems. The classifications are from the survey results. The critical scores used to determine recommendations for the WRA system are described in the text.

	System		
	AQIS	Panetta	WRA
% of all species (n=370)			
Serious weeds not accepted	99	100	100
Minor weeds not accepted	95	93	84
Non-weeds not rejected	89	74	93
Useful species not rejected	73	45	74
Species to be evaluated	39	20	29
% of agricultural weeds (n=132)			
Serious weeds not accepted	99	100	100
Minor weeds not accepted	94	94	94
Non-weeds not rejected	64	42	66
% of environmental weeds (n=190)			
Serious weeds not accepted	99	100	100
Minor weeds not accepted	96	98	88
Non-weeds not rejected	66	47	66

All three systems produced *evaluate* recommendations for a proportion of the species. The proportion was 39, 20 and 29% using the AQIS, Panetta and WRA systems, respectively (Table 4). This could be misleading since the selection of species is not necessarily typical of the species likely to be encountered as imports. It is more informative to consider the number requiring *evaluation* within each survey classification (Figure 5). In all systems, a low proportion (9-14%) of serious weeds required *evaluation*. For reasons discussed above, the AQIS system had a very large proportion of non-weeds and minor weeds requiring *evaluation*. *Evaluation* should predominate in the minor weed classification. The WRA system was closest to achieving this objective since this category contained the greatest proportion of species requiring *evaluation*.

Evaluate recommendations increased and *reject* recommendations decreased as the usefulness of the plant increased (Figure 5), particularly for the AQIS and WRA systems.

As an overall indicator of system performance, recommendations are summarised in Table 4 and correlations are given in Table 5. All system recommendations are significantly correlated to the survey classifications, but the WRA system shows the best relationship.

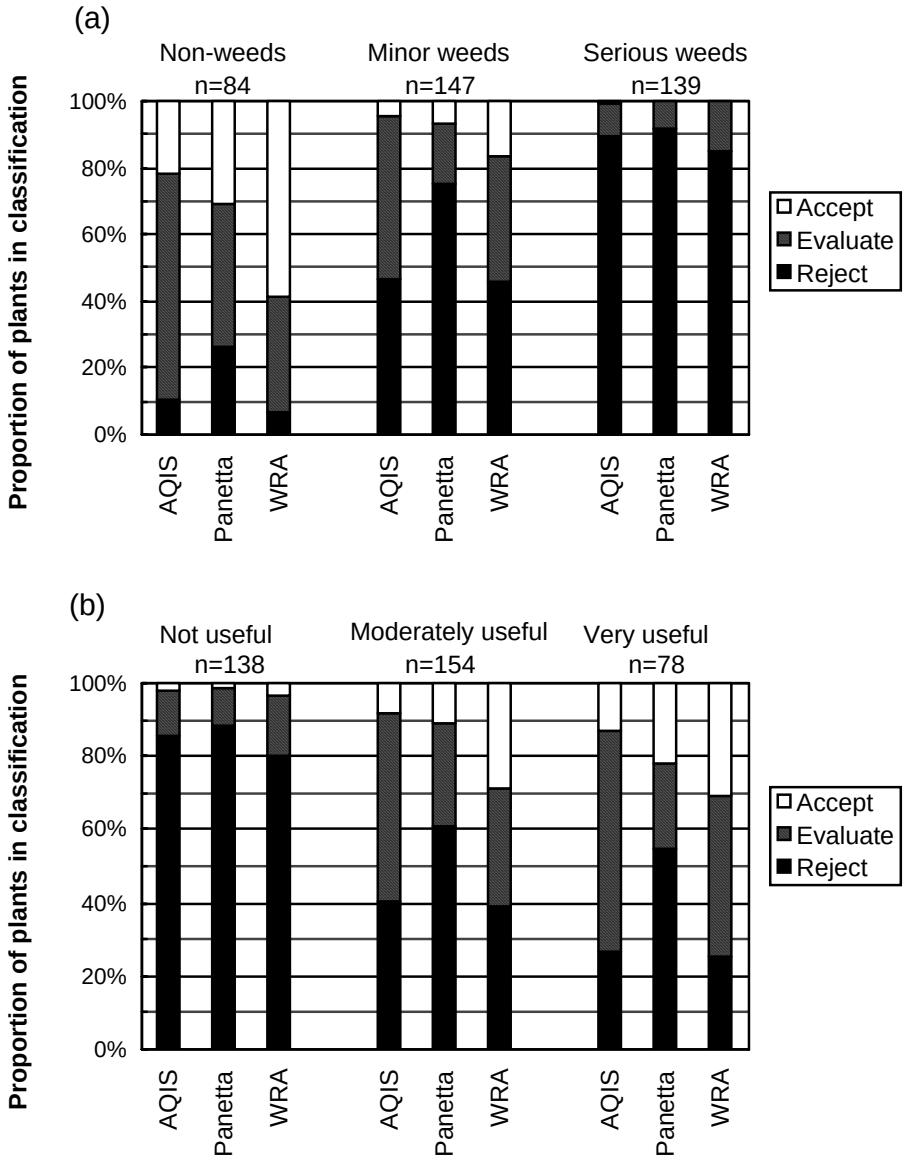


Figure 5 Partitioning of assessment recommendations, as produced by the AQIS, Panetta and WRA systems, within the three survey classifications for weediness (a) and usefulness (b).

Table 5 Rank correlations for the three assessment system recommendations and the survey classifications.

	Survey	AQIS	Panetta
AQIS	**0.60**		
Panetta	**0.53**	0.47	
WRA	**0.65**	0.66	0.47

Components of the WRA system

The effectiveness of the three sections of the WRA system were examined to determine the contribution made to the overall recommendation. Most combinations are significantly correlated (Table 6), but undesirable attributes are the most poorly related to other components of the system. The biological/ecological attributes, reproduction, dispersal and persistence, do show some relationship to documented behaviour of the plant elsewhere in the world (biogeography). Overall, the WRA system is well correlated to the survey classifications, and all components make significant contributions. Biogeography is the best measure of weed potential in Australia, and this is consistent with other studies (Panetta 1993, Scott and Panetta 1993).

Examination of the relative value of the individual questions has not been attempted here. It is expected that if the system were adopted, such details would be evaluated so that questions can be reworded, added, deleted or replaced on the basis of accumulated experience.

Table 6 Correlations of the WRA score, its components, and the survey classifications.

	WRA	Bio-geography	Undesirable attributes	Biology /ecology
Biogeography	0.80			
Undesirable attributes	0.46	0.28		
Biology/ecology	0.80	0.46	0.19	
Survey	0.69	0.62	0.44	0.50

Agricultural and environmental weeds

The WRA system has some capacity to detect environmental weeds and identify them as such.

The weeds were partitioned into the two main categories, agricultural and environmental weeds. Figure 4 shows the cumulative frequency distributions for each subset. Of the species classified as weeds in the survey, 31% were regarded as both environmental and agricultural weeds, 35% were environmental weeds only and 15% were agricultural weeds only. The remaining 19% were weeds in other categories (Table 3).

There were no obvious differences in the ability of any of the systems to make appropriate recommendations for weeds of either category (Table 4). It is difficult to make reasonable comparisons the performance of the AQIS and WRA systems because of the large proportion of *evaluate* recommendations generated by the AQIS system. In comparison to the overall performance, a higher proportion of agricultural weeds and, to a lesser extent, environmental weeds were identified by the WRA system, which implies that weeds in other sectors (amenity, horticultural, etc.) were less effectively identified.

Rank correlations of the system recommendations against the survey classifications were similar for agricultural and environmental weeds. Correlations for the WRA and AQIS systems did not differ significantly (Table 7).

The WRA score could be partitioned into agricultural and environmental components (section 0). Each score partition was best correlated to the corresponding survey category (Table 8).

Table 7 Rank correlations of the assessment systems recommendations with the survey categories.

	Survey	
	agricultural	environmental
AQIS	0.47	0.45
Panetta	0.34	0.39
WRA	0.48	0.46

Table 8 Correlations of the WRA score with the survey categories.

	Survey	
	agricultural	environmental
WRA - agricultural	0.58	0.41
WRA - environmental	0.44	0.51
WRA- all weeds	0.53	0.52

Conclusions

The ability of the WRA system to make reliable recommendations has a sound quantitative basis, and the mechanism is transparent. These features are basic requirements for establishing phytosanitory conditions in accordance with the GATT SPS agreement.

The success rate of the WRA system in predicting weed potential, using the survey classifications as a guide, was good (r=0.69***). No serious weeds were accepted and the majority of minor weeds were also not accepted. Less than 10% of non-weeds were rejected but some of these were considered useful species. It is expected that most of these would get an *evaluate* recommendation if more of the assessment questions were answered.

The WRA system performed best overall although, in many respects, the AQIS system performed similarly. However, the AQIS system has the disadvantage of making no provision for lack of information pertaining to the questions, resulting in a recommendation to *evaluate* a large proportion of the species. The Panetta system was the most severe, largely due to the more rigorous treatment of the *weed elsewhere* question. Panetta was reluctant to relax the rigour of this question because of the precautionary principle and the reasonable expectation that widely naturalised species, newly introduced to Australia, could become weedy.

There were no obvious differences in the performance of the systems in screening for weeds of agriculture or the environment, although there was some evidence that the WRA system was able to categorise species on this basis. In other words, the WRA system could be made to identify species that are likely to be of concern in one sector only.

The WRA *evaluate* recommendation identifies plants which are likely to impose an economic cost if they become established, including the cost of enviromental damage. Where possible, quantitative cost/benefit analysis, using risk analysis techniques, could be used to decide if the risk is accapetable.

Table 9.Partitioning of species by WRA score and survey classification

Score	Serious Weeds	Minor Weeds	Non-weeds
Accept			
-14			**Camellia japonica** Abelia chinensis
-13			Cedrus atlantica
-12			Magnolia campbelli
-11			Araucaria araucana Chamaecyparis pisifera
-10			Acer palmatum **Lens culinaris**
-9			Antirrhinum majus Meconopsis betonicifolia Paphiopedilum insigne
-8			Stapelia nobilis
-7		Buddleia crispa	Abies nordmanniana Lupinus albus Paulownia fortunei Romneya coulteri Welwitschia mirabilis
-6		Aloe ferox Cistus ladanifer	Aesculus hippocastanum Berberis thunbergii Encephalartos lehmannii Gnetum gnemon **Raphanus sativus** **Trifolium alexandrinum**
-5		Aristolochia elegans	Lilium mackliniae Lophophora williamsii **Pisum sativum** Rafflesia arnoldi **Secale cereale** Taxus baccata
-4		Buddleia davidii	**Cucumis melo** **Prunus amygdalus** **Triticum aestivum**
-3		Chamaecyparis lawsoniana	**Fagopyrum sp** Pandanus latifolia **Panicum coloratum** Taxus wallichiana
-2		Chasmanthe floribunda **Digitaria decumbens** Melilotus alba Reseda odorata Scabiosa atropurpurea **Vicia narbonensis** Viola arcuata	Ephedra fragilis Eragrostis tef Lupinus "Russell" hybrids **Themeda triandra**
-1		Cichorium intybus Lathyrus sativus Orbea variegata Phleum pratense Psoralea patens	**Lupinus angustifolius** **Trifolium hirtum** **Vigna radiata**
0		Chamaecytisus proliferus Lycium chinense Malcolmia africana **Pinus radiata** Poa trivialis **Stylosanthes scabra**	**Arbutus unedo** **Cicer arietinum** **Hordeum vulgare** **Lycopersicon esculentum** Trifolium semipilosum **Vicia villosa**

Table 9.Partitioning of species by WRA score and survey classification

Score	Serious Weeds	Minor Weeds	Non-weeds
Evaluate			
1	Cinnamomum camphora Salix babylonica Themeda quadrivalvis	Achillea ptarmica Chloris truncata Eschscholzia californica Gazania linearis Homeria elegans	Avena byzantina **Avena sativa** Cineraria lyrata Erythroxylum coca **Trifolium incarnatum** **Trifolium resupinatum**
2	Pinus halepensis **Olea europea**	**Agrostis stolonifera** Echinochloa polystachya Freesia leichtlinii X alba **Poa pratensis** Stylosanthes hamata **Trifolium subterraneum**	Cajanus cajan **Dactylis glomerata** **Glycine max** **Solanum tuberosum** Stylosanthes montevidensis **Zea mays**
3	Gleditsia triacanthos **Leucaena leucocephala** Protoasparagus densiflorus Soliva pterosperma	Bromus unioloides Cannabis sativa Cassia floribunda Chloris gayana Dolichos sericeus **Festuca arundinacea** Festuca rubra Freesia refracta Gorteria personata Grindelia camporum Limonium sinuatum Panicum miliaceum Paspalum plicatulum Zoysia japonica	**Desmodium heterophyllum** **Helianthus annuus** **Setaria italica** **Sorghum bicolor** **Trifolium fragiferum**
4	Cucumis myriocarpus	Albizia lebbek Arundo donax Erythrina crista-galli Lycium barbarum Monadenia bracteata Panicum virgatum Phalaris canariensis Prunus cerasifera **Trifolium pratense** **Trifolium repens**	Coix lachryma-jobi Stylosanthes viscosa **Trigonella foenum-graecum** Vigna hosei **Vigna luteola**
5	Cotoneaster pannosa Datura stramonium Raphanus raphanistrum Rapistrum rugosum Watsonia bulbillifera	**Asparagus officinalis** **Cynodon dactylon** Dipsacus fullonum Hymenachne acutigluma Hyparrhenia hirta **Lablab purpureus** **Lathyrus hirsutus** **Lolium multiflorum** Paspalum nicorae Reseda phyteuma Robinia pseudoacacia Toxicodendron radicans Urochloa panicoides	**Medicago sativa** Pelargonium asperum **Pueraria phaseoloides** **Sorghum sudanese**
6	Desmodium uncinatum Echium vulgare Eragrostis curvula Homeria pallida Pentzia suffruticosa Wedelia trilobata	Bothriochloa pertusa Bromus mollis Gomphocarpus physocarpus **Lolium perenne** Lupinus cosentinii Lythrum salicaria **Macroptilium lathyroides** **Panicum maximum var. jacq**	Eleusine coracana Stenotaphrum secundatum **Tanacetum cinerariaefolium**
Reject			
7	**Cenchrus ciliaris** Ehrharta calycina Zizyphus spina-christi	**Acer negundo** **Andropogon gayanus** Berkheya rigida	**Panicum antidotale** **Panicum coloratum var. makarikariense** **Paspalum virgatum**

Table 9.Partitioning of species by WRA score and survey classification

Score	Serious Weeds	Minor Weeds	Non-weeds
		Cenchrus setiger **Clitoria ternatea** Crotalaria goreensis **Desmodium intortum** Digitaria pentzii Eremocarpus setigerus Gymnocoronis spilanthoides Hirschfeldia incana Hyparrhenia rufa **Lolium rigidum** **Macroptilium atropurpureum** **Macrotyloma axillare** Melinis minutiflora **Panicum bulbosum** Setaria palmifolia Spartina anglica Stevia eupatoria Stylosanthes humilis Xanthium strumarium	**Vigna unguiculata**
8	Calepina irregularis Cardaria draba Ludwigia peruviana Onopordum illyricum	Bromus catharticus Calluna vulgaris Echinochloa colona Leucanthemum vulgare	
9	Avena fatua Carthamus leucocaulos Chondrilla juncea Coccinia grandis Conium maculatum Echium plantagineum Foeniculum vulgare Myagrum perfoliatum Pueraria thunbergiana	Alnus glutinosa Melilotus indica Panicum repens **Paspalum dilatatum** Phalaris minor **Setaria sphacelata** Sorghum almum **Urochloa mosambicensis** Vicia sativa	
10	Amsinkia spp Cyperus rotundus Equisetum arvense Heliotropium amplexicaule Homeria miniata Ligustrum lucidum Lycium ferocissimum Scolymus maculatus Senecio pterophorus	Brachiaria decumbens Citrullus lanatus Ecballium elaterium **Paspalum notatum** Pennisetum purpureum	
11	Ambrosia confertiflora Cenchrus echinatus Heliotropium europaeum Hypericum perforatum Kochia scoparia Onopordum acaulon	Ailanthus altissima Eragrostis tenuifolia Erica lusitanica Pennisetum pedicellatum Toxicodendron succedaneum	Dactyloctenium aegyptium

Table 9.Partitioning of species by WRA score and survey classification

Score	Serious Weeds	Minor Weeds	Non-weeds
Reject (continued)			
12	Asphodelus fistulosus Cortaderia richardii Echinochloa crus-galli Glyceria maxima Marrubium vulgare Orobanche ramosa Picnomon acarna	Axonopus compressus Centaurea nigra Chloris barbata Diplotaxis tenuifolia Euphorbia lathyris **Pennisetum clandestinum** Silene vulgaris	Stylosanthes guianensis
13	Brachiaria mutica Centaurea calcitrapa Chrysanthemoides monilifera Oxalis latifolia Sida rhombifolia Thunbergia grandiflora Zantedeschia aethiopica	Andropogon virginicus Gomphocarpus fruticosus Iva axillaris Paspalum distichum **Phalaris aquatica**	
14	Ageratina adenophora Ambrosia tenuifolia Cytisus scoparius Euphorbia terracina Nassella trichotoma Salvia reflexa	Citrullus colocythis Euphorbia heterophylla Pennisetum polystachion	
15	Acanthospermum hispidum Calotropis procera Cenchrus incertus Eichhornia crassipes Holcus lanatus Homeria flaccida Juncus acutus Senecio madagascariensis Solanum elaeagnifolium Sporobolus africanus	Pennisetum macrourum	
16	Cabomba caroliniana Carduus nutans Chromolaena odorata Cortaderia selloana Cryptostegia grandiflora Cynara cardunculus Protasparagus plumosus Sagittaria graminea Silybum marianum	**Panicum maximum var. trichoglume** Reseda lutea Typha latifolia	
17	Alternanthera pungens Ambrosia artemisiifolia Carthamus lanatus Centaurea solstitialis Convolvulus arvensis Dittrichia graveolens Myrsiphyllum asparagoides Sarothamnus scoparius	Anthemis cotula Hypericum tetrapterum Sorghum X almum	
18	Cyperus aromaticus Cyperus eragrostis Parthenium hysterophorus Pistia stratiotes	Ceratophyllum demersum Genista monspessulana Hypericum androsaemum	

Table 9.Partitioning of species by WRA score and survey classification

Score	Serious Weeds	Minor Weeds	Non-weeds
Reject (continued)			
19	Allium vineale Ambrosia psilostachya Baccharis halimifolia Carduus pycnocephalus Eriocereus martinii Pyracantha angustifolia Senecio jacobaea Ulex europaeus Xanthium occidentale Xanthium spinosum		
20	Acroptilon repens Cortaderia jubata Lagarosiphon major Opuntia robusta Opuntia stricta Opuntia vulgaris Protasparagus aethiopicus	Hydrilla verticillata Pennisetum villosum	
21	Cirsium arvense Cirsium vulgare Lantana camara	Allium triquetrum	
22	Alternanthera philoxeroides Cuscuta campestris Egeria densa Opuntia aurantiaca Scolymus hispanicus		
23	Elodea canadensis		
24	Onopordum acanthium		
25	Sagittaria montevidensis Sorghum halepense		
26	Ageratina riparia		

References

Anon. (1992). International Plant Protection Convention. Rome, FAO.

Anon. (1995). International Standards for Phytosanitary Measures. Sections 1. Guidelines for Pest Risk Analysis (draft standard). Rome, FAO.

Hazard, W. H. L. (1988). Introducing crop, pasture and ornamental species into Australia - the risk of introducing new weeds. Australian Plant Introduction Review **19**, 19-36.

Hnatiuk, R. J. (1990). Census of Australian vascular plants. Canberra, Australian Government Publishing service.

Holm, R. J., Pancho, J. V., Herberger, J. P. and Plucknett, D. L. (1979). *A geographical atlas of world weeds*. New York, John Wiley and Sons.

Panetta, F. D. (1993). A system of assessing proposed plant introductions for weed potential. Plant Protection Quarterly **8**, 10-4.

Panetta, F. D., Pheloung, P. C., Lonsdale, M., Jacobs, S., Mulvaney, M. and Wright, W. (1994). Screening plants for weediness: a procedure for assessing species proposed for importation into Australia. A report commissioned by the Australian Weeds Committee.

Panetta, F. D. and Scanlan, J. C. (1995). Human involvement in the spread of noxious weeds: what plants should be declared and when should control be enforced? *Plant Protection Quarterly* **10**, 69-74.

Parsons, W. T. and Cuthbertson, E. G. (1992). Noxious weeds of Australia. Melbourne, Inkata Press.

Scott, J. K. and Panetta, F. D. (1993). Predicting the Australian weed status of southern African plants. Journal of Biogeography **20**, 87-93.

APPENDIX 3

Biosecurity Australia information on the Weed Risk Assessment System

The Weed Risk Assessment system

The Weed Risk Assessment (WRA) system is a question-based scoring method. Using the WRA involves answering up to 49 questions on the new species to be imported. The questions include information of the plants; climatic preferences, biological attributes, reproductive and dispersal method. The WRA uses the responses to the questions to generate a numerical score. The score is used to determine an outcome: *accept*, *reject* or *further evaluate* for the species. The WRA also makes a prediction as to whether a species may be a weed of agriculture or the environment.

How to answer the WRA system's questions

An image of the WRA system is presented Form A - Weed Risk Assessment question sheet (gif - 204 Kb)- this image can be printed. The scoring sheet for the WRA system is also available Form B - Weed Risk Assessment scoring sheet (gif - 19Kb)

As you can see the answers to most of the questions in the system is yes (y), no (n) or don't know (leave blank). A few questions require a number as a responce.

How the WRA system generates a score

A typical score for a question is: *Yes* =1 point , *No* = -1 or 0 and *Don't Know* = 0

The climate and weed elsewhere questions differ from the typical scoring system in that they generate a score using a weighting system. The score given for Question 2.01 and 2.02 is used to weight the scores for `yes' answers in the weed elsewhere questions (3.01 to 3.05). The quality of climate data greatly affects the climate match. A good climate match increases the probability that a species will behave the same way in Australia as it does overseas. The weediness score increases if the information used to produce the climate match is not comprehensive, due to the greater uncertainty introduced by this data.

Two other questions do not fit into the standard scoring system. A score of `no' for Question 3.01, whether a plant has naturalised overseas, is modified by the score to Question 2.05, its history of repeated export. Species with repeated introductions outside of their native range that have not established are a lower risk. Question 6.07, the minimum generative time, requires the input of a numerical score. This generative time is standardised by the use of a correlation factor (1 year scores 1, 2-3 years' scores 0, greater than or equal to 4 years' scores -1).

The system compares the total score for a species to the critical values to determine the recommendation for the species. The threshold values for the system are, if the plant scores: less than 1, accept the plant for import, greater than 6, reject the importation of the plant and from 1 to 6, further evaluation the plant.

The threshold values are the product of the assessment of over 370 species. This species used for the calibration of the system ranged from severe agricultural and environmental weeds to benign and beneficial plants.

The system tallies the number of questions answered in each section. The WRA system allows for knowledge gaps, while still requiring responses to a minimum number of questions in each of its three different categories. The minimum number of questions for each section is: 2 for section A, 2 for section B and 6 for Section C.

The WRA system has some capacity to suggest the type of ecosystems likely to be affected by the plant assessed. The system indicates if the plant is more likely to be a specific weed of agriculture or the general environment, once it has assessed the plants potential to become a weed in Australia. A species may be assessed to be a weed of both categories. The partitioning helps to identify areas most at risk from the characters assessed for the species.

Do I need a computer?

The WRA system was developed to allow an assessment to be made without a computer (Form A). Form B sets out the method for manual calculation of the final score.

What computer software do I require to run the WRA system?

The WRA system is designed to run on Microsoft Excel version 5.x. It may be run on either a Windows or Macintosh computer. The system is also in the process of being adapted to run under Access 2.0 and 7.0.

If you would like a copy of the WRA Excel program contact Plant Biosecurity.

Using the WRA Excel spreadsheet

The WRA Excel spreadsheet consists of two worksheets. The risk assessment (RA) worksheet is the species assessment questionnaire (Form A). This worksheet can be filled out manually or by using the run command. The WRA worksheet is dynamically linked to the second worksheet, the Species sheet. This Species worksheet is the data worksheet for the system. All species assessed under the system are stored in this worksheet. New species added to the RA worksheet are listed at the bottom of the Species list.

Risk Assessment (RA) Sheet Buttons

> *Run* - Runs the dialogue driven risk assessment. Alternatively, manual entry is possible.
> *Get* - This button has two functions. It brings the responses for a specified species from the Species sheet to the RA sheet. Also new species can be added to the list by selecting `new' in the pop-up box. The system will you to type the genus and species, common name and author into a pop-up box.
> *Store* - Transfers the current responses in the RA sheet to the Species sheet. Note that this does not save results to disk (see save).

Species - Switches to the Species worksheet.
Save - Saves the current state of the system to disk.
Help - Provides information on the operation of the system, including discussion of the questions and information on button functions.
Print Report - Creates a one page report of the risk assessment, Form A. Prints this report on the currently selected printer.

Species Sheet Buttons

Get - Allows you to find a species or add a new one to the list. It is possible to enter and modify responses directly on the species sheet but the scores will not be updated. To update the score, the species will need to be moved to the RA sheet using the RA sheet *Get* button and then restored to the species sheet using the RA *Store* button.
Delete - Delete a species from the sheet.
Sort - Sorts the species sheet alphabetically by botanical name.
RA - Switches to the RA worksheet.
Save - Saves the current state of the system to disk.
Help - Provides information on the operation of the system.

How should I interpret the questions in the WRA system?

The Weed Risk Assessment system consists of 49 questions.
A description of each question has been developed.
Users of the WRA should try to follow these descriptions so that all users of the system answer the questions consistently.

History/Biogeography

1 Domestication / cultivation

Is the species highly domesticated? If answer is `no" go to Question 2.01

1.01 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.

Has the species become naturalised where grown?

1.02 Is a domesticated plant, which has introduced from another region, growing, reproducing and maintaining itself in the area in which it is growing. A `yes' answer to question 1.01 will be modified by the response to this question.

Does the species have weedy races?

1.03 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.

2 Climate and distribution

Species suited to Australian climates (0-low; 1-intermediate; 2-high)

2.01 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).

Quality of climate match data (0-low; 1-intermediate; 2-high)

2.02 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.

Broad climate suitability (environmental versatility)

2.03 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.

Native or naturalised in regions with extended dry periods

2.04 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.

Does the species have a history of repeated introductions outside its natural range?

2.05 This history should be well documented. A potential weed must have opportunities to show its potential. A score for Question 2.05 will modify the score for a `no' answer to Question 3.01. Species with repeated introductions that have not established are a lower risk.

3 Weed Elsewhere

Naturalised beyond native range

3.01 A naturalised 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.'

Garden/amenity/disturbance weed

3.02 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.

Weed of agriculture/horticulture/forestry

3.03 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.

Environmental weed

3.04 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.

Congeneric weed

3.05 Documented evidence that one or more species, with similar biology, within the genus of the species being evaluated are weeds.

Biology/Ecology

4 Undesirable traits

Produces spines, thorns or burrs

4.01 The plant possesses a structure on the plant 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.

Allelopathic

4.02 The plant is well documented as a potential suppressor of the growth of other species by chemical (eg. hormonal) means. Such evidence is rare throughout the whole plant kingdom.

Parasitic

4.03 The parasite must have a detrimental effect on the host and the potential hosts must be present in Australia. This question includes wholly and semi-parasitic plants. Such plants are rare.

Unpalatable to grazing animals

4.04 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.

Toxic to animals

4.05 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.

Host for recognised pests and pathogens

4.06 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 takeall, should not be the basis for answering `yes' for an individual species.

Causes allergies or is otherwise toxic to humans

4.07 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.

Creates a fire hazard in natural ecosystems

4.08 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.

Is a shade tolerant plant at some stage of its life cycle

4.09 Shade tolerance can enhance the invasive potential of a species.

Grows on infertile soils

4.10 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.

Climbing or smothering growth habit

4.11 This trait includes fast growing vines and ivy's that cover and kill or suppress the growth of the supporting vegetation. Plants that rapidly produce large rosettes could also score for this question.

Forms dense thickets

4.12 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.

5 Plant type

Aquatic

5.01 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. Consequently, the score is high (5).

Grass

5.02 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.

Nitrogen fixing woody plant

5.03 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.

Geophyte

5.04 Perennial plants with tubers, corms or bulbs. This question is specifically to deal with plants that have specialised 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.

6 Reproduction

Evidence of substantial reproductive failure in native habitat

6.01 Predators and other factors present (eg. 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.

Produces viable seed

6.02 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.

Hybridises naturally

6.03 A `yes' answer for this question requires documented evidence of interspecific hybrids occurring, without assistance, under natural conditions.

Self-fertilisation

6.04 Species capable of self seeding, can spread from seed produced by an isolated plant.

Requires specialist pollinators

6.05 The invasive potential of the plant is reduced if the species requires specialist pollinating agents that are not present or rare in Australia.

Reproduction by vegetative propagation

6.06 The plant must be capable of increasing its numbers by vegetative means. This may include reproduction by: rhizomes, stolons or root fragments, suckers or division.

Minimum generative time (years)

6.07 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).

7 Dispersal mechanisms

Propagules likely to be dispersed unintentionally

7.01 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.

Propagules dispersed intentionally by people

7.02 The plant has properties that make it attractive or desirable, such as an edible fruit, an ornamental or curiosity. The species is readily collected as a cutting or seed. This group includes most horticultural plants.

Propagules likely to disperse as contaminants of produce

7.03 Produce is the economic output from any agricultural, forestry or horticultural

activity. An example is grain shipments that contain seeds of weed species.

	Propagules adapted to wind dispersal
7.04	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 and plants with seeds contained within an explosive capsule or pod.
	Propagules buoyant
7.05	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.
	Propagules bird dispersed
7.06	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.
	Propagules dispersed by other animals (externally)
7.07	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.
	Propagules dispersed by other animals (internally)
7.08	The propagules are eaten by animals, dispersed and will grow after defecation.
8	**Persistence attributes**
	Prolific seed production
8.01	The level of seed production must be met under natural conditions and applies only to viable seed. For grasses and annual species this rate should be (>5000-10000/m^2/yr), for woody annual a rate of (>500/m^2/yr) 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.
	Evidence that a persistent propagule bank is formed (>1 yr)
8.02	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 plants invasive potential.
	Well controlled by herbicides
8.03	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.
	Tolerates or benefits from mutilation, cultivation or fire
8.04	Plants that tolerate or benefit from such disturbance may out-compete other species. This question does not apply to seed banks.
	Effective natural enemies present in Australia
8.05	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.

Assessments may be entered manually into Form A and the final score calculated by reference to Form B.

Acknowledgements

The Weed Risk Assessment system was developed by Dr Paul Pheloung during his employment in Western Australian Department of Agriculture.

Input from a wide range of contributors has been instrumental in the finalisation of the WRA system. During the calibration phase input, including assessments using the system and comments on the system, was received from scientists from 13 organisations from both Australia and New Zealand. After the system was endorsed by the Australian Weeds Committee it was released to stakeholders of the Australian Quarantine and Inspection Service (AQIS) and the Australian Nature Conservation Agency (now a group within Environment Australia), the two Commonwealth agencies with an interest in the regulation of imported plants for comment. Comments from both groups were used to increase the effectiveness and clarify the questions used in this system, this contribution is greatly acknowledged.

Form A - Weed Risk Assessment question sheet

Form B - Weed Risk Assessment scoring sheet