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A Weed Risk Assessment Model for Screening Plant Imports into New Zealand

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Landcare Research Contract Report: LC9596/080

PREPARED FOR:

MAF Policy
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Wellington

July 1996

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Part 2: The risk assessment manual

Part 3: The NZWRA database (on diskette only)

Summary

Project and client

A weed risk assessment model was evaluated by Peter A. Williams, Landcare Research New Zealand Ltd, Nelson, for MAF Policy.

Object

To evaluate a computer-based weed risk assessment model developed in Australia (WRA) with the assistance of New Zealand scientists, and adapt it for use as a potential border control tool in New Zealand.

Method

Only minor alterations were made to the model to adapt it to New Zealand conditions, e.g., those relating to climate, to produce the NZWRA model. The score sheets for approx. 293 taxa, and most of the gazetted noxious plants in New Zealand, were modified as if it were proposed to import the taxa into New Zealand. To verify the model, 11 people in various occupations were asked to rank the taxa for weediness on a three-point scale: major weed, minor weed, and non-weed. The ranks were averaged, and the taxa were assigned to the three classes. These averaged rank scores were compared with the scores from the model.

Results

Part One of this report summarises the evaluation of the model under Australian conditions. Part Two describes the results of evaluating the NZWRA model. Virtually all plants (98%) ranked as major weeds were rejected, including all taxa currently classed as noxious plants in New Zealand, and the majority of minor weeds were either rejected (65%) or required further evaluation (27%). Most non-weeds (64%) were accepted. The variance for the weediness classification from the respondents was predictably high, and related largely to perceived usefulness.

Conclusions

The model is an objective, credible, and relatively quick risk assessment system able to screen large numbers of potential new entries.

Recommendations

The NZWRA system should be adopted as a screening tool for proposed plant imports into New Zealand, in conjunction with other systems for evaluating weediness and undertaking cost-benefit analyses.

Part 1

1. Introduction

MAF Regulatory Authority is charged under the Biosecurities Act with ensuring that all plant taxa proposed to be brought into New Zealand which are not prohibited, and which are not already here, must be evaluated for their potential weediness. This requires an objective, credible, and publicly acceptable risk assessment system to screen the large number of potential new entries. It is proposed that part of the assessment use a modified computer-based system developed in Australia (Pheloung 1995). MAF engaged Landcare Research to evaluate the Australian model (WRA) for use in New Zealand.

The basis of the WRA model is that it uses a scoring system to assign each prospective import to one of three numerical classes, which is then converted into a recommendation:

1) accept - the plant taxon is allowed into the country;
2) reject - the plant taxon is not allowed into the country;
3) evaluate - more information is required, either to re-run the model, or from more intensive investigations (e.g., field trials), before a decision can be made.

The WRA model is not intrinsically dependent on computers for either its operation or its validity, but the amount of information generated from studying many plant taxa makes computers essential. A preliminary study in November 1994 by a group of New Zealand botanists (Halloy 1994) showed the system to have potential for use here. Since then, the model has been further revised after extensive consultations in Australia and New Zealand, validated for Australian conditions (Pheloung 1995), and released for trial in Australia.

The aim of the present investigation was to alter the WRA model according to the recommendations in Halloy (1994), in so far as this can be done, and then to determine how well the revised model (NZWRA) would operate in New Zealand.

Part 1 of this report contains the background to the WRA model's rationale and operation, and the methods used to evaluate it in Australia, which are directly transferable to New Zealand. Section 1.2 is therefore paraphrased, and often drawn verbatim, from the Australian report (Pheloung 1995) with little modification other than to make the wording relevant to New Zealand. (In the interests of clarity, verbatim sections are not indicated individually.) Section 1.3 contains the evaluation of the system for New Zealand, including the scores from the evaluation trial in Table 6.

Part 2 is the manual for operating the WRA system. It includes the system score sheets and operating instructions for using the system. With the exception of the guidelines for answering the questions, which have been modified for the NZWRA system, this section is directly from Pheloung (1995).

Part 3 is the NZWRA database on diskette.

2. The weed risk assessment system (WRA)

An acceptable WRA system for border control must meet a number of requirements:

1) The system should be calibrated and validated against a large number of taxa already present in Australia/New Zealand, representing the full spectrum of plant taxa likely to be encountered as imports.

2) It must be shown that the screening procedure is reasonably effective at discriminating between plants already identified as weeds or non-weeds, as an indication of its likely effectiveness when dealing with plants not yet in the country and those which are being officially controlled.

3) The data set resulting from testing plants already in the country should be used to adjust the scoring system such that the majority of weeds are rejected, the majority of non-weeds are accepted, and the proportion requiring evaluation is kept as small as possible.

4) International agreements require that prohibited taxa should fit the definition of a quarantine pest (see box, below). The assessment procedure should be fully transparent and based on sound scientific principles so that New Zealand cannot be accused of applying artificial non-tariff trade barriers.

5) Resources needed to operate the WRA system should be realistic - the cost in time and money to the importer and MAF Regulatory Authority should be as low as possible.

6) The system should be capable of identifying environmental weeds as compared to, e.g., agricultural or horticultural weeds, and identifying them as such. This could be necessary, since environmental weeds may not fit the definition of a quarantine pest as commonly interpreted (see box).

7) In the majority of instances, 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 'taxa' is used in this report to cover taxa at all levels, including subspecies and varieties.

International trade agreements (Anon. 1992, 1994) allow countries to regulate the entry of plants and plant products to prevent the entry of pests. The use of such non-tariff barriers should be applied to quarantine pests only. (The following definitions are subject to formal amendment of the International Plant Protection Convention.)

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.

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

The first tier of the screening system determines whether a plant taxon requires WRA. Part of this involves determining whether the taxon is a potential quarantine pest (see box, above). If a taxon is already widely distributed, then the limitation of further introductions of the pest may serve no useful purpose. Phytosanitary control of the entry of a taxon is appropriate where the proposed introduction is significantly different genetically, and the difference has pest implications.

If the taxon is present, but not widely distributed, official control of the existing infestations is essential for the taxon to qualify as a pest. Regulatory organisations (regional councils, Department of Conservation, etc.) are charged with deciding which taxa should be officially subject to eradication. Prohibiting entry of a plant into New Zealand is appropriate only where such judgments have been made concerning specific plant taxa.

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 category 3 - *evaluate*. This would also be required should the importer legally challenge a category 2 - *reject* outcome.

Evaluation includes a number of options:

1. Repeat the WRA system, using additional information;

2. Undertake an economic cost/benefit analysis to justify the risk;

3. Post-entry evaluation in the form of experimental 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.

2.1 The WRA system

The system seeks to produce recommendations according to the principles proposed by Dane Panetta (Panetta 1993), and which are directly applicable to New Zealand:

1) Weeds from other parts of the world should not be allowed entry (*rejected*) if the climate in the country of origin is similar to that in New Zealand.

2) Otherwise, taxa with biological attributes suggestive of invasive plants or weeds should be subjected to *evaluation*.

3) Otherwise, taxa should be *accepted*.

In view of the difficulty in definitively predicting weed potential, the precautionary principle should be applied to all decisions:

> It is better to erroneously reject a plant taxon that would confer a net benefit than to erroneously admit one that would cause a loss or damage.

Structure

Answers are sought for questions on historical, biogeographical, and biological/ecological details of the candidate plant taxon.

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, modified to suit New Zealand, is described in Section 3, and the question sheet is given in Part 2, Forms A and B.

> 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. It is incorporated into a computer-based environment to accelerate the process, help enforce objectivity, and automatically maintain a database of assessed taxa. A complete set of responses for each taxon 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 2, Forms A and B). There is no requirement to answer all questions.

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 structure of the WRA system. It is also possible for a plant taxon that has not been particularly weedy to become so in a new situation. The remainder of the system attempts to identify such candidates by determining relevant biological attributes.

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

1) Biogeography: includes the documented distribution, climate preferences, and weediness of a plant taxon in other parts of the world. The distribution and climate preferences should be used to predict a potential distribution in New Zealand. In fact, such data from country of origin is rarely available, and the default is to assume that the taxon will readily grow unaided in New Zealand.

2) Undesirable attributes: these are attributes related to noxious or invasive behaviour. They are similar to those used in the system devised by Esler (Esler *et al.* 1993) for evaluating noxious plants in New Zealand.

3) Biology/ecology: these are the attributes that contribute to the capacity of the taxon to reproduce, spread, and persist. These are also similar to the characters used by Esler *et al.* (1993) to determine the biological success rating of weeds.

In most instances, one point is added for a weedy attribute and one point is deducted for a non-weedy attribute. Grading or weighting the relative importance of the various questions was avoided as being too subjective, with one exception: the score for an aquatic plant is 5 points.

Some questions are modified by the outcomes to other questions. For example, 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 taxa from those requiring *evaluation* and the higher critical score separates taxa requiring *evaluation* from those that should be *rejected.* The positioning of these critical scores in the Australian version was determined by a calibration process using information on weeds, non-weeds and other economically important plants that are present in Australia. Their positioning to suit New Zealand conditions is discussed in Section 3.4.

An attempt was made to classify the questions according to their relevance in identifying attributes associated with agricultural, environmental, and nuisance weeds (Part 2 , Form A), although these are not precisely defined. Nearly half of the questions (22) were allocated to one of these categories, 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 taxon is probably a potential environmental weed only.

Information required to operate the WRA system

A routine WRA should take 1-2 days per plant taxon 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 frequently assessed taxa are dealt with and assigned to the schedules of either prohibited or approved taxa.

However, Australian and New Zealand assessors are not likely to have detailed knowledge of new plant taxa introductions, and assessments 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 taxa in Australia, the various Landcare Research databases at Lincoln, the Lesser-Known Plants database at Crop and Food Research, Invermay, and world floras for native and naturalised distributions (to determine climate preferences) from libraries at Landcare Research, Lincoln, and Crop and Food, Invermay. A very recent source is the list of weeds of North America, compiled by the National Coalition of Exotic Pest Plant Councils.

Electronic resources for information acquisition are becoming increasingly accessible and useful. The Kew Index, the basic tool for taxonomic verification and geographic origin, is available on CD-ROM. Abstracting systems 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 forms provide a means of rapidly obtaining relevant unpublished or obscure information, particularly on taxa 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 of all plant taxa in New Zealand.

The worldwide distribution of a taxon can be used to determine the degree and extent of similar climates in Australia/New Zealand. At least two programs (*Climex*, CSIRO Division of Entomology, Qld; *Climate*, Department of Agriculture, WA) can perform this climate matching task without difficulty for Australia. Such information is not readily available for New Zealand, although there has been some progress in this area, e.g., the Australian program *Plantgrow* has been trialed at Invermay (S. Halloy, pers. comm.). Such investigations take a great deal of time and are therefore very costly. In the absence of such research, a good match should be assumed unless the natural distribution of the taxon clearly does not coincide with any New Zealand climates; this would probably imply only tropical and desert regions. Simplified maps of the 20 or so major climatic zones of the world can be found in good atlases, and can be used to answer 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 using the model and other tools should precede the arrival of

the plant material at the barrier, an accurate and unambiguous identification of the proposed import is essential. A record of the sources of information and the taxon identification authority would need to be recorded. There is only limited provision for this in the model score sheet, with a space for the assessor's initials.

Information on the taxa likely to be encountered at the border 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*, but this is not the case nor the intention. For many taxa there will be uncertainty that cannot be resolved without direct evaluation under New Zealand environmental conditions.

2.2 Calibrating and testing the WRA system in Australia

The WRA system was tested by analysis of its performance for 370 plant taxa (270 of which are also found in New Zealand - Section 3.3.1) representing weeds from agricultural, environmental, and other sectors, and useful taxa. The system was judged on its ability to correctly *reject* weeds, *accept* non-weeds, and generate a low proportion of taxa requiring *evaluation*. The performance of the system was compared to that of the other systems used in Australia, e.g., the AQIS System based on Hazard (1988).

The tests involved 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 taxa having noxious weed status in Australia were included.

Assessors were asked to treat each taxon as if it had not yet arrived in Australia. Taxa that are serious weeds in Australia, for example, were to be assessed purely on their weed status outside Australia. Results were checked and inconsistencies were altered, using Holm *et al.* (1979) and Parsons & Cuthbertson (1992) as authorities.

Modifications based on expert comment

Australian workers, and a group of New Zealand botanists including the author (Halloy 1994), provided critical comment on the outcomes of this original system. The analysis of the system's performance is based on the modified version. An appraisal of the comments provided is given in Pheloung (1995).

Two important suggestions from Australian workers, which were not adopted in the modifications, were commented on by Pheloung (1995):

- *Grasses as a life-form should not automatically be assessed as weeds just because many grasses are serious weeds.*

Although 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 (e.g., readily established, spreading, and self-sustaining). These considerations are more appropriate at the *evaluate* stage, if the taxon falls into this category.

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

The pre-entry assessment should consider weed potential without regard to the sector at risk or the economic benefits. It is expected that all taxa 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 taxa

Twelve Australian scientists classified each taxon for weediness and usefulness on a 0-2 scale. They were asked to give responses only for taxa 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 survey was intended to provide a reference measure of the weed status, in Australia, of the assessed taxa. The weed status of each taxon is derived from the collective opinion of from one to twelve experts. The analyses are based on taxa for which at least two opinions were provided. Although the majority of taxa (81%) are perceived as weeds in some context, less than half were considered to be serious weeds. (Pheloung (1995) does not give the actual threshold for these scores.) A wide range of non-weeds and useful taxa, some of which are also considered to be weeds, was included. Weeds from all sectors (agriculture, environment, etc.) were well represented (Table 3; Pheloung 1995).

2.3 Performance of the WRA system

Critical values

In the 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 taxa required *evaluation*.

The range of scores for non-weeds overlapped the range for serious weeds, so it was impossible to define critical values that would reject all serious weeds while accepting all non-weeds. However, it was 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 taxa assessed in the Australian 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. Consequently the critical scores of 0 and 7 were used to convert the WRA scores into the recommendations, *accept, evaluate*, and *reject*.

A summary of one aspect of the results of the Australian assessment system is shown in Table 1. (The original from which this is derived, table 4 in Pheloung (1995), includes comparisons with other systems which are not relevant here.)

Table 1. Distribution of recommendations for the WRA system. The classifications are from the Australian survey results. The critical scores used to determine recommendations for the WRA system are described in the text (from table 4 in Pheloung 1995).

Classification outcome	%
All taxa (n=370)	
Serious weeds not accepted	100
Minor weeds not accepted	84
Non-weeds not rejected	93
Useful taxa not rejected	74
Taxa to be evaluated	29
Agricultural weeds (n=132)	
Serious weeds not accepted	100
Minor weeds not accepted	94
Non-weeds not rejected	66
Environmental weeds (n=190)	
Serious weeds not accepted	100
Minor weeds not accepted	88
Non-weeds not rejected	66

A number of useful agricultural taxa, particularly grasses, were rejected in the Australian study. In many instances this was 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 attributes of these taxa could lower the score into the *evaluate* range. However, for *Bromus* species the outcome would probably be *reject,* for the reasons discussed in Section 3.3.

A comparison of the WRA system with other systems used in Australia showed it to be just as successful at rejecting serious weeds, but with the advantage of being least severe in rejecting non-weeds and allowing the highest proportion of useful taxa (30%).

All the Australian systems produced *evaluate* recommendations for a proportion of the taxa: 29% using the WRA system. This score may be misleading, since the selection of taxa in the trial is not necessarily typical of the taxa likely to be encountered as imports. It was more informative to consider the number requiring *evaluation* within each survey classification, because this is a better test of their relative ability to discriminate between weeds and non-weeds. In the WRA system a low proportion (approx. 14%; fig. 4 in Pheloung 1995) of 'serious' weeds required *evaluation*. *Evaluation* should predominate in the 'minor weed' classification, and this proved to be the case.

Evaluate recommendations increased and *reject* recommendations decreased as the usefulness of the plant increased in the WRA system (fig. 4 in Pheloung 1995).

Components of the WRA system

The effectiveness of the three sections of the WRA system – Biogeography, Undesirable attributes, and Biology/ecology (see Part 2) – was examined to determine the contribution made to the overall recommendation. Most combinations are significantly correlated (Table 2), but undesirable attributes are the most poorly related to other components of the system; e.g., undesirable traits such as toxicity are not closely correlated with attributes such as reproductive mode or whether the plant taxon is suited to Australian climates. 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 score is well correlated to the survey classifications, and all components make significant contributions. Biogeography was the best measure of weed potential in Australia, and this is consistent with other studies (Panetta 1993, Scott & Panetta 1993).

Table 2. Correlations of the WRA score, its components, and the survey classifications (from table 6 in Pheloung 1995).

	WRA	Biogeography	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

The relative value of the individual questions in determining the final score was not considered by Pheloung (1995). It was expected that if the system were adopted, such details would need to be evaluated so that questions can be reworded, added, deleted, or replaced on the basis of accumulated experience. This has been partially done in modifying the system for New Zealand, as explained in the next section.

The weeds were partitioned into the two main categories, agricultural and environmental weeds. Of the taxa classified as weeds in the Australian 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

of horticulture, gardens, or service areas.

Rank correlations of the system recommendations against the survey classifications were similar for agricultural and environmental weeds, 0.48 and 0.46 respectively (table 7 in Pheloung 1995).

The WRA score could be partitioned into agricultural and environmental components (Section 2.1). Each score partition was best correlated to the corresponding survey category (Table 3). That is, the score generated by the model for agricultural weeds, correlated best with the weeds considered to be agricultural weeds and so the model has some ability to predict which sector is likely to be affected.

Table 3. Correlations of the WRA score for agricultural and environmental, with the survey categories (from table 8 in Pheloung 1995).

WRA component	Survey classification	
	Agricultural	Environmental
WRA - agricultural	0.58	0.41
WRA - environmental	0.44	0.51
WRA - all weeds	0.53	0.52

2.4 Australian conclusions

Pheloung (1995) concluded that the WRA system was able to make recommendations on a reliable scientific basis, and the assumptions involved in the procedure are explicit. This should ensure that the requirements of international trade agreements are met.

The success rate of the WRA system in predicting weed potential, using the survey classifications as a guide, was good ($r = 0.69$, $p < 0.05$). No plant taxa considered by the panel to be 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 to be useful. 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 of the three Australian systems tested. Moreover, the WRA system was able to categorise taxa as environmental or agricultural weeds, and could be adapted to identify taxa that are likely to be of concern in one sector only.

The WRA *evaluate* recommendation identifies both those taxa which are likely to impose an economic or environmental cost if they become established, and those which would pose little or no risk. Where possible, quantitative cost/benefit analysis, using risk analysis techniques, could be used to decide if the risk is acceptable.

3. Modifying the Weed Risk Assessment system for New Zealand (NZWRA)

To evaluate the WRA system specifically for New Zealand (see Part 1.1 for the early history of this process) three main topics needed consideration:

1) The recommendations of the New Zealand team that considered the 1994 draft of the model had to be examined in relation to the revised WRA system, to determine whether further changes were required.

2) Assess whether other modifications were needed to make the model applicable to New Zealand.

3) Evaluate whether the revised system (termed the NZWRA system) would be suitable for use on at least a trial basis in New Zealand.

3.1 The New Zealand suggestions

A comparison of the list of suggested modifications to the original WRA system made by the New Zealand team (Halloy 1994) with the revised WRA system shows that the majority, in so far as they could be expected to be applicable to weeds in both Australia and New Zealand, were incorporated into the WRA system (Appendix 1). An explanation of those that were not acted on is given in Pheloung (1995). None of these are of such importance that they would alter the integrity of the WRA system.

It could therefore be expected that the WRA system would give similar results in New Zealand to its performance in Australia, even after further minor alteration. This assumption is based on the premise that 73% of the taxa used in the WRA evaluation are found in both countries, where they have broadly similar responses.

3.2 The alterations undertaken to WRA to create the NZWRA system

The most significant changes made to WRA by the author following the recommendations of Halloy (1994) to create NZWRA involved the following questions (Note: in the actual model, the term 'species' is used rather than 'taxa'):

Q2.01 Species suited to New Zealand climates.

Q2.04 Native or naturalised in regions with equable climates.
The WRA system asked if a plant was native or naturalised in regions with extended dry periods. Such a question was not applicable to New Zealand where, considering the country as a whole, the climate is mainly equable.

Q3.03 Weeds of agriculture/forestry/horticulture

The WRA system did not specifically include forestry or commercial horticulture in the questions, but both are important in the New Zealand economy.

Q4.10 Tolerates a wide range of soil conditions.
The WRA system identifies low-fertility soils as being particularly prone to invasion in Australia, whereas in New Zealand tolerance of a wide range of soil conditions is more likely to be conducive to a plant becoming a weed.

Q8.04 Tolerates or benefits from mutilation, cultivation, or fire.
The WRA system did not mention fire, yet in New Zealand fire tolerance or ability to recover from fire is an important aspect of some weeds, partly because most of the indigenous flora are not fire tolerant.

Other minor changes to the wording were made. None of the modified questions required alteration of the scoring system, that is, where a 'Yes' answer gave a positive score in WRA it would also be positive for NZWRA.

3.3 Testing the NZWRA system

The main purpose of the model is to distinguish weeds from non-weeds, while not rejecting an unacceptable proportion of potentially useful plants. Since few changes were made to the system to adapt it to New Zealand conditions, and none of these changes required changes to the scoring system, the assumption was made that most of the Australian findings (Section 2.3) would be applicable to the model in New Zealand. Moreover, there are general similarities between Australian and New Zealand systems, for example, there are many temperate grasses and ornamental shrubs that are just as useful in Australia as they are in New Zealand. It was decided, therefore, that taxa on the WRA database could form the bulk of the data to test NZWRA locally, after their scores were checked for New Zealand conditions. There is the distinct possibility, however, that plants which are considered to be weeds in Australia are not treated as weeds here, and vice versa. Thus it became necessary to determine the perceived 'weediness' of all the plant taxa in New Zealand.

Updating the NZWRA system database

The WRA question sheets for 270 taxa, derived by matching the WRA list of taxa against the Landcare Research database at Lincoln, were checked and amended to make the answers conform to information from overseas, and to ensure that answers likely to be applicable to Australia but not to New Zealand were suitably altered. These alterations were made entirely by the present author (P.A.W) from a wide range of literature, floras, and databases.

A further 23 taxa not on the WRA database that are gazetted noxious plants in New Zealand were added. The main source of information was Esler *et al.* (1993), although care was taken not to include information that would have been gained primarily from the weeds' behaviour in New Zealand. This is because for new plant imports, such hindsight information is not available.

The combined list still has some Australian bias, but this is considered unlikely to have an effect on evaluating the model in New Zealand.

Comparing WRA and NZWRA scores

The main questions to be altered concerned the suitability of New Zealand climates and the quality of the climate match (Q2.01 and Q2.02). Many taxa in the WRA had scores of 1 for both these questions. Most New Zealand taxa had to be scored a 2 for both questions, i.e., the default score, because climate models are either not available or else they are too time consuming to apply. The net result is to raise the final NZWRA score by 1 point.

Pinus species were recorded on WRA as not being naturalised in regions with dry climates, yet they are severe weeds of the fynbos vegetation in South Africa (Richardson *et al.* 1993). They are also weeds in equable climates in South America (Richardson *et al.* 1993), so that scores for *Pinus* spp. were higher in NZWRA.

Some scores were increased by changes to the important Section 3, concerning weediness elsewhere. This had an influence on several taxa, including economically important plants. None of the *Bromus* species in WRA had 'yes' answers for other species of the genus being weeds, yet several *Bromus* species are weeds elsewhere in the world, the best known being *Bromus tectorum* in North America (Mack 1986). All *Bromus* species in NZWRA had their scores increased by 2 with a 'yes' answer for this question.

Several taxa were scored in WRA as not being weeds elsewhere, whereas they are considered as such in New Zealand, particularly weeds of conservation. However, most of this information is not published in the international literature (e.g., Williams & Timmins 1990) and would not have been accessible to Australian workers. In contrast, the present author had access to the WRA database itself, and other databases on Australian weeds (Berry & Mulvaney 1995; Carr *et al.* 1992) provided information enabling these questions to be answered 'yes' to several taxa in NZWRA, thereby raising the score by at least one point.

Another question that often required to be changed was Q8.05, concerning natural enemies. Many WRA taxa had a 'yes' answer, possibly because of seed-eating birds and other animals, but most NZWRA taxa were answered 'no', thereby increasing the score by 1.

The net outcome of these differences between the WRA scores and the NZWRA scores, excluding the additional noxious plants, was that the NZWRA scores were higher by an average of 1.60, with a standard deviation of 2.98.

The net effect was to change the outcomes for only 12 taxa, or four percent of the taxa common to both WRA and NZWRA. In most instances, the recommendation was changed from *evaluate* to *reject,* and in one, from *accept* to *evaluate* (Table 4).

Table 4. Taxa with scores that were changed from the WRA database to the NZWRA database sufficiently to after their recommendations.

Name	Common name	WRA score	WRA outcome	NZWRA score	NZWRA outcome	Score difference
Asphodelus fistulosus	asphodel	4	evaluate	19	reject	14
Bromus unioloides	prairie grass	3	evaluate	7	reject	4
Cynodon dactylon	couch	5	evaluate	8	reject	3
Datura stramonium	thornapple	5	evaluate	6	reject	1
Dipsacus sylvestris	teasel	5	evaluate	9	reject	4
Echium vulgare	viper's bugloss	5.5	evaluate	8	reject	2.5
Eragrostis curvula	African lovegrass	4	evaluate	7	reject	3
Lolium perenne	perennial ryegrass	5	evaluate	12	reject	7
Lupinus 'Russell' hybrids	Russell lupin	-2	accept	4	evaluate	6
Lycium barbarum	Chinese boxthorn	4	evaluate	6	reject	2
Prunus cerasifera	cherry plum	4	evaluate	7	reject	3
Spartina anglica	ricegrass	5	evaluate	12	reject	7

Determining weediness in New Zealand

The weediness of a taxon in New Zealand was determined by seeking the opinions of 11 people engaged in botany, agriculture, conservation, or forestry. As people think of different systems when they assess weediness, it was anticipated that answers would differ between individual professional groups (Perrins *et al.* 1992). An effort was made to ensure an equal weighting between those broadly involved in agriculture/forestry and those working in biodiversity/conservation, and professional botanists with a foot in both camps. Most of the 11 people had no prior knowledge of the project. They were provided with an outline of the reasons behind the project, the workings of the WRA system, and the list of 293 taxa. Taxa were to be classified as (1) non-weeds, (2) minor weeds, and (3) serious weeds in the same way as had been done by Pheloung (1995). The results are termed 'class scores' to distinguish them from WRA or NZWRA scores. Weediness was not defined, but participants were asked *not* to take usefulness into account, and examples were given of useful and economically important plants that were also weeds. They were asked not

to consult the literature in making their responses.

Some respondents were clearly influenced by either the economic value of some taxa on the one hand, even though these are known to require control in some circumstances, or by the point of view that virtually all adventive plants are weeds. This was expected in view of the fact that only personal opinion was sought, and that similar results have been recorded previously (Perrins *et al.* 1992). Nevertheless, all data was incorporated into the evaluation. This was done by averaging the class scores for all the respondents' answers and dividing the results into the following classes, derived from the mid-points between initial class scores: non-weed 1.0–1.50; minor weed, 1.51–2.49; and serious weed 2.50–3.0. Note that these divisions have a very slight tendency to minimise the number of minor weeds.

Response to questionnaires: Replies from 11 people were used for the analysis of NZWRA, and only taxa with at least three scores were used in subsequent phases of the investigation. This resulted in the number of taxa being reduced to 197, although taxa with at least one score are given in Table 7. The higher minimum number of scores (cf. a minimum of 2 responses used by Pheloung 1995) of relatively poorly known taxa, and the consequent lower number of taxa for the analysis, was adopted in an attempt to use only taxa with which the community – as represented by the 11 respondents – was moderately familiar. It was hoped that this approach would maximise initial public acceptability of the model.

Table 5. The coefficients of variation (%) of the class scores derived from questionnaires for taxa scored as major weeds, minor weeds, or non-weeds by at least 3 respondents.

	n	Range	Mean	S.D.
Major weed	40	0-54	28.4	17.4
Minor weed	132	0-59	26.5	14.4
Non-weed	25	0-34	18.8	7.3

The variability in the scores was high, as was expected, with an average coefficient of variation ranging from 18.8 to 28.4, and as high as 59.0 (Table 5). Only 10 taxa had a coefficient of 0, indicating perfect agreement among those who scored the taxon. Agreement was highest in taxa with the lowest scores, that is, those with average scores that categorised them as non-weeds. The coefficients of variation were as high for minor weeds as for major weeds. Again, these outcomes are not surprising, since many plants were scored as major weeds by those with an environmental bias, and as non-weeds by some of those with an agricultural bias.

3.4 Performance of the NZWRA system

Of the 40 taxa classed as major weeds in New Zealand by at least 3 respondents, all but 2 of them (98%) were rejected by the NZWRA system (Table 6). These exceptions had an *evaluate* or *accept* outcome, the latter being *Buddleja davidii*. No noxious plants were accepted, despite some being classed as minor weeds

(Table 7).

Of the 132 minor weeds, 64.4% were rejected, while 27.3% and 8.3% had scores for *evaluate* and *accept* respectively. The accepted taxa covered a wide range of forms, including shrubs, dicotyledonous herbs, and grasses.

Of the 25 non-weeds, 64% were *accepted*, while 28% and 8% had scores for *evaluate* and *reject* respectively. The two rejected non-weeds, *Ailanthus altissima* and *Lavandula stoechas*, both have some weedy characteristics and are found wild in New Zealand.

Table 6. The recommendations of NZWRA for taxa scored for weediness in three categories, by at least three respondents, as a percentage of the total in each category.

Category	n	Accept	Evaluate	Reject
All taxa	197	15	19	66
Major weeds	40	2	2	96
Minor weeds	132	8	27	65
Non-weeds	25	64	28	8

Despite the slight changes to the questions in the model, and the higher taxa scores in the NZWRA, the above percentages are very similar to those produced by the WRA system, e.g., non-weeds not *rejected* (*accepted* plus *evaluate*) are 92% and 93% for NZWRA and WRA respectively (cf. Tables 1, 6). The main difference between the two systems is the relatively higher proportion of minor weeds *rejected* by NZWRA. This will have been caused by the addition to the list of most noxious plants in New Zealand, many of which were scored only as minor weeds, while at the same time removing many non-weed taxa from the NZWRA database because of their being not found in New Zealand or else failing to reach the threshold of 3 replies for inclusion in the analysis.

The critical scores in the WRA system used to determine the outcomes were placed to minimise the proportion of taxa to *evaluate*, since this is a primary requirement of the system. As the proportions of taxa to *reject, evaluate,* or *accept* were similar for both WRA and NZWRA, the critical scores are considered to be suitable for NZWRA. A random selection of plants proposed to be brought into New Zealand would undoubtedly contain a much lower proportion of known weeds, and consequently the overall proportion likely to receive an *accept* or *evaluate* score would be higher. Until a much larger database has been developed for NZWRA by applying it to actual proposed imports, the critical scores should remain as they are. The general conclusions as to the functioning and usefulness of the model, as summarised from Pheloung (1995) in Part 1 of this report, are likely to be as applicable in New Zealand as they are in Australia.

The serious and minor weeds rejected include a wide range of weeds of agriculture, forestry, and the

environment (Table 7). The NZWRA , as did the WRA, showed a considerable ability to indicate whether taxa were likely to be weeds of agriculture or of the environment (see the NZWRA database for details).

The NZWRA scores showed only a moderate relationship with the mean weediness scores generated from the questionnaire ($r = 0.50$, $p < 0.05$). This is partly the result of the narrow range of these scores (1–3) and the relatively low proportion of non-weeds in the sample.

Pheloung (1995) also tested the ability of the WRA to distinguish between useful and non-useful taxa, and noted that some useful taxa were rejected (Table 1). No attempt was made to do this for NZWRA because, as explained, the conclusions from the WRA system with respect to these aspects are considered to be as applicable in New Zealand as in Australia. Moreover, it was taken for granted here that some useful taxa would be rejected, on the basis that some questions asked by the system are rooted primarily on biological/ ecological grounds which identify attributes common to both useful plants and weeds (Lonsdale 1994). This proved to be the case, and any model designed to screen weeds primarily on these grounds must reject taxa that are useful yet invasive, e.g., *Agrostis stolonifera*, *Lupinus* 'Russell' hybrids, and *Pinus contorta*. Even so, the diversity of the minor weed taxa and the few major weeds accepted, illustrates the impartiality of the system with respect to what botanists call 'habit'.

Whether the economic benefits that rejected taxa might bring to New Zealand could justify their introduction would need to be the result of an economic evaluation and environmental impact assessment involving experimental studies (Lonsdale 1994), as is at present the case for the proposed importation of biological control organisms. The NZWRA would assist this process by indicating the sector which is likely to view the plant as a weed and, conversely, the sector unlikely to be affected.

The relatively high percentage of weeds with an *evaluate* score reflects the paucity of information available for many plants proposed to be imported. Better information would reduce the proportion of taxa to evaluate.

4. New Zealand conclusions

The NZWRA has the ability to detect virtually all major weeds in New Zealand, whether of agriculture/ forestry or the environment, or just nuisance weeds. The system has some ability to indicate which sector is likely to be affected and, as Pheloung (1995) concluded, could be modified to show this more clearly.

The fact that some useful plants may be potentially *rejected* in this process, and that many taxa will require *evaluation* on the basis of the information available, means that ancillary procedures should be in place to gather more information about a taxon's biology, ecology, and potential for control, and to undertake cost/benefit analysis once this information has been obtained.

A major benefit of the NZWRA system is that it is transparent, with clear assumptions regarding weed attributes. In contrast, expert opinion as to the weediness of a plant in New Zealand, just as in Britain (Perrins *et al.* 1992), will always be variable and biased towards particular environments.

Progress in determining weediness will be gained mainly from a greater understanding of the factors that make specific habitats prone to invasion, and the particular attributes of the invading taxa that enable them to exploit these habitats. In the absence of such detailed information for many land use systems, the NZWRA appears to do an excellent job of predicting which plants could become major weeds in New Zealand.

The NZWRA system should be adopted as a screening tool for proposed plant imports into New Zealand, in conjunction with other systems for evaluating weediness and undertaking cost/benefit analyses.

5. Acknowledgments

This report rests on the work of Paul Pheloung and his collaborators in Australia, and I am very thankful for help given by Paul throughout the project. The project was undertaken in New Zealand through the efforts of Godwin Balasingam of MAF Regulatory Authority, and was funded by MAF Research.

Those who provided the New Zealand data are thanked profusely, but I do not wish to identify them because they were not advised that their opinions might become widely known, even by guesswork. Mark Ryan helped me understand the workings of the computer-based model in order to make the minor changes. Bill Lee and Stephan Halloy made helpful comments on the script. The text was typed by Merle Rae and edited by Tymone Duval and Melanie Newfield.

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Appendix 1: Partitioning of species by NZWRA Score and Survey classification. All species are included. Species not naturalised marked *

A. Accept

Score	Major weeds	Minor weeds	Non-weeds
-14			*Camellia japonica*
-13			*Cedrus atlantica*
-12			*Aucuba japonica*
-11			*Magnolia campbelli* *Araucaria araucana*
-10			*Chamaecyparis pisifera*
-9		*Lupinus albus* *Antirrhinum majus*	*Acer palmatum*
-7		*Abies nordmanniana*	*Meconopsis betonicifolia* *Paulownia fortunei* *Romneya coulteri* *Welwitschia mirabilis*
-6		*Berberis thunbergii*	*Aesculus hippocastanum* *Cistus ladanifer* *Pisum sativum*
-5		*Raphanus sativus*	*Secale cereale* *Aristolochia elegans* *Triticum aestivum*
-4		*Eragrostis tef* *Taxus baccata*	
-3	*Buddleja davidii*	*Chasmanthe floribunda*	*Taxus wallichiana* *Cucumis melo*
-2	*Themeda triandra*	*Melilotus albus* *Phytolacca octandra*	
-1		*Echium fastuosum* *Scabiosa atropurpurea* *Reseda odorata* *Trifolium hirtum* *Lupinus angustifolius* *Cichorium intybus* *Phleum pratense*	*Arbutus unedo*

B. Evaluate

Score	Major weeds	Minor weeds	Non-weeds
0		*Avena byzantina* *Lathyrus sativus** *Gazania linearis* *Poa trivialis* *Chamaecyparis lawsoniana* *Trifolium subterraneum*	
1		*Cajanus cajan** *Chloris truncata* *Vicia villosa* *Trifolium resupinatum* *Trifolium incarnatum* *Cannabis sativa* *Avena sativa* *Solanum tuberosum*	*Zea mays*
2	*Watsonia bulbillifera*	*Celtis australis** *Leucaena leucocephala** *Pinus halepensis* *Cinnamomum camphora** *Gleditsia triacanthos* *Olea europaea* *Phalaris arundinacea* *Betula pendula* *Salix babylonica* *Eschscholzia californica* *Pinus radiata* *Poa pratensis*	*Malcolmia africana* *Freesia refracta*
3	*Carex longebrachiata*	*Festuca rubra* *Trifolium fragiferum* *Dactylis glomerata*	*Panicum miliaceum* *Setaria italica* *Cucumis myriocarpus* *Sorghum bicolor* *Helianthus annuus*
4	*Lupinus* 'Russell' hybrids	*Lathyrus ochrus** *Gliricidia sepium** *Phalaris canariensis*	*Trigonella foenum-graecum* *Limonium sinuatum* *Lycopersicon esculentum*
5	*Lathyrus cicera**	*Erythrina crista-galli* *Achillea ptarmica* *Lolium multiflorum* *Asparagus officinalis* *Medicago sativa*	

C. Reject

Score	Major weeds	Minor weeds	Non-weeds
6	*Pinus nigra*	*Ornithogalum umbellatum* *Chloris gayana* *Clitoria ternatea** *Gomphocarpus physocarpus* *Lycium barbarum* *Stenotaphrum secundatum* *Arundo donax* *Tussilago farfara* *Acer negundo* *Datura stramonium* *Trifolium repens*	
7	*Eragrostis curvula* *Pinus contorta*	*Ehrharta calycina* *Indigofera hirsuta** *Lolium rigidum* *Setaria palmifolia* *Lythrum salicaria* *Rapistrum rugosum* *Xanthium strumarium* *Prunus cerasifera* *Trifolium pratense* *Raphanus raphanistrum* *Rosa canina*	*Melinis minutiflora* *Wedelia trilobata*
8	*Zizania latifolia* *Calluna vulgaris*	*Dalbergia sissoo** *Setaria sphacelata* *Gymnocoronis spilanthoides* *Nuphar lutea* *Cynodon dactylon* *Echium vulgare* *Festuca arundinacea*	*Lavandula stoechas*
9	*Chrysanthemoides monilifera*	*Senna tora* *Hirschfeldia incana* *Paspalum paniculatum* *Cardaria draba* *Chondrilla juncea* *Ricinus communis* *Paspalum dilatatum* *Dipsacus fullonum* *Avena fatua* *Alnus glutinosa* *Hypericum perforatum* *Vicia sativa*	

Score	Major weeds	Minor weeds	Non-weeds
10	*Berberis darwinii*	*Emex australis* *Pennisetum purpureum* *Orobanche minor* *Solanum mauritianum* *Agrostis stolonifera* *Marrubium vulgare*	
11	*Ecballium elaterium* *Ligustrum lucidum*	*Citrullus lanatus* *Gomphocarpus fruticosus* *Kochia scoparia* *Solanum carolinense* *Papaver somniferum* *Bromus mollis* *Foeniculum vulgare* *Bromus catharticus*	
12	*Zoysia japonica* *Salia reflexa* *Spartina anglica*	*Cassia alata** *Aster subulatus* *Axonopus compressus* *Parietaria officinalis* *Echinochloa crus-galli* *Parietaria judaica* *Echium plantagineum* *Pennisetum clandestinum* *Leucanthemum vulgare* *Lolium perenne*	*Jatropha curcas*
13	*Equisetum arvense* *Ulex europaeus*	*Andropogon virginicus* *Sida rhombifolia* *Salvia reflexa* *Centaurea calcitrapa* *Vallisneria spiralis* *Silene vulgaris* *Reseda luteola* *Phalaris aquatica* *Robinia pseudacacia* *Verbascum thapsus* *Zantedeschia aethiopica* *Solanum rostratum*	*Ailanthus altissima* *Thunbergia grandiflora*
14	*Cyperus rotundus* *Berberis glaucocarpa* *Glyceria maxima*	*Brachiaria mutica* *Diplotaxis tenuifolia* *Euphorbia lathyris* *Conium maculatum* *Proboscidea louisianica**	

Score	Major weeds	Minor weeds	Non-weeds
15	*Phragmites australis* *Nassella trichotoma*	*Cestrum parqui* *Sporobolus africanus* *Xanthium spinosum* *Mentha pulegium*	
16	*Eichhornia crassipes*	*Cassia occidentalis** *Parkinsonia aculeata** *Tribulus terrestris* *Cynara cardunculus* *Centaurea nigra* *Juncus acutus* *Urtica dioica* *Holcus lanatus* *Hypericum tetrapterum*	
17	*Myriophyllum aquaticum* *Carduus nutans* *Lycium ferocissimum* *Hedychium gardnerianum*	*Dittrichia graveolens* *Alternanthera pungens* *Centaurea solstitialis* *Carthamus lanatus* *Anthemis cotula* *Galega officinalis*	
18	*Nymphoides geminata* *Erica lusitanica*	*Ambrosia artemisiifolia* *Crataegus laevigata** *Pyracantha angustifolia* *Argemone mexicana** *Cyperus eragrostis* *Convolvulus arvensis* *Hypericum androsaemum* *Oxalis latifolia*	
19	*Silybum marianum* *Crataegus monogyna*	*Argemone ochroleuca* *Asphodelus fistulosus*	
20	*Salpichroa origanifolia* *Pistia stratiotes*	*Lantana montevidensis* *Pennisetum villosum* *Reseda lutea* *Rumex brownii* *Rumex pulcher* *Carduus acanthoides* *Carduus pycnocephalus* *Rumex conglomeratus* *Rumex obtusifolius* *Rumex crispus*	
21	*Ageratina adenophora*	*Nymphoides peltata* *Carthamus lanatus* *Solanum linnaeanum*	

Score	Major weeds	Minor weeds	Non-weeds
22	*Oxalis pes-caprae* *Hydrilla verticillata* *Ceratophyllum demersum* *Alternanthera philoxeroides* *Senecio jacobaea* *Cirsium arvense* *Clematis vitalba*	*Allium vineale* *Allium triquetrum* *Cuscuta campestris* *Teline monspessulana* *Cirsium vulgare* *Opuntia vulgaris*	
23	*Cytisus scoparius* *Egeria densa* *Cytisus scoparius* *Lagarosiphon major* *Hedychium flavescens* *Cortaderia jubata*		
24	*Paspalum distichum* *Lantana camara* *Elodea canadensis* *Pennisetum macrourum*	*Onopordum acanthium*	
25	*Sorghum halepense* *Cortaderia selloana* *Rosa rubiginosa*		
26		*Sagittaria graminea* *Ranunculus acris*	
28	*Ageratina riparia*		
29	*Rubus fruticosus*		

Addendum: Since all the analysis were completed, four taxa were removed from the database as they are no longer recognised as being present in New Zealand.

Appendix 2. Modifications suggested by New Zealand botanists (November 1994) to adapt the original WRA model to New Zealand conditions.

The document below is the original list of changes suggested, together with the changes that have been made since, either by the Australians as presented by Pheloung (1995), or subsequently by P.A.W. Note that the model does not readily allow addition or subtraction of questions without compromising its operation. These notes are included not to enable an historical analysis of each question in the model, but to provide evidence that most of the concerns of the original group of New Zealand botanists who examined the prototype model in November 1994 (Halloy 1994) have been considered in the present model.

1.01: Where it says "50 years", should say "20 GENERATIONS". This interacts with 6.07.
Done.

1.02: No response to 1.02 reinforces non-weediness strongly. Where it says "reduces" should say INCREASES and change macro accordingly.
Done.

1.03: No response to 1.03 reinforces non-weediness strongly. Where it says "reduces" should say INCREASES and change macro accordingly.
Done.

2. "Climate and distribution MATCH"
The questions in this section are wider than simply seeking a match, and no change has been made.

2.01: Species suited to ANY NEW ZEALAND climates.
Done.

2.02: Is irrelevant at present in New Zealand as we do not have the appropriate models, but it may be left in for the time being as it will not affect the outcome if answered consistently.
The model assumes a score of 2 if no climate data is available.

2.03: Leave as is.
Done.

2.04: Delete and replace by "NATIVE OR NATURALISED IN REGIONS WITH OCEANIC CLIMATES", and in comments: "NEW ZEALAND'S MILD EQUABLE CLIMATES ARE WELL SUITED TO PLANTS FROM SIMILAR CLIMATE TYPES, AND LESS TO THOSE FROM CONTINENTAL CLIMATES".
Done.

2.05: Delete this item entirely.
Not done.

3. Leave.

3.01: Found beyond native range, BUT NOT CULTIVATED. This question can only be yes if either 7.01 or 7.02 is yes. If this is the case, this value must weigh those, i.e., if 7.01 or 7.02 is yes and 3.01 is no, it must reduce value of 7.01 and 7.02 to 0; if 3.01 is yes, then 7.01 and 7.02 may be added up. The relation is similar to that between 1.02 and 1.01.
The question clearly implies that it refers to non-cultivated situations.

3.02: Delete and replace by "MAGNITUDE OR PROBLEM AS A WEED (0, 1, 2)", and in comments: "ESTIMATE THE MAGNITUDE OF THE DELETERIOUS EFFECT OF THIS PLANT IN TERMS OF COST OF CONTROL, PRODUCTIVITY LOSSES OR ENVIRONMENTAL DEGRADATION ON A SCALE OF 2 (HIGH EFFECT) TO 0 (NO EFFECT)". THIS VALUE MUST MULTIPLY 3.03, 3.04, 3.05, 3.06.
Most questions in the model are not scaled, for the reasons outlined by Pheloung (1995).

3.03: Weed of agriculture OR HORTICULTURE. In comments delete "Agriculture" and start with "Incurs", delete everything after "losses".
Changed to agricultural/forestry/horticulture weed and changes in the notes.

Insert new 3.04: "WEED OF COMMERCIAL FORESTS". In comments: "INCURS A COST FROM CONTROL OF THE PLANT OR PRODUCTIVITY LOSSES".
This is included in the present model under Q3.03, discussed above.

3.04: Now 3.05: In comments: delete and replace by "INCURS A LOSS OF ENVIRONMENTAL VALUES, AMENITY VALUES OR A COST OF CONTROL".
Changes made to accommodate part of this.

3.05: Now 3.06.

4. Leave.

4.01: Leave.

4.02: Delete entire item.
If assessors do not feel confident in attributing allelopathic effects, Q. 4.02, they can ignore it.

4.03: Delete entire item.
Similar response to above, for parasitic, Q4.03.

4.04 to 4.09: Leave as they are.

4.10: "SHADE TOLERANT at some stage of its life cycle".
Done.

4.11: Delete entire item.
The present Q4.10 has been changed to indicate tolerance of a wide range of soil conditions.

4.12: Delete "Climbing or", leave "Smothering growth habit".
Not changed, now Q4.11.

4.13: Leave.

5. Leave.

5.01: Delete "Free floating", change to "Aquatic PLANT".
Done.

5.02: Delete entirely and replace by "CLIMBER", and in comments: "THIS ITEM INTERACTS WITH 4.12". If 4.12 is 0, this item becomes 0 even if the answer is "yes".
Climbing habit is considered in Q4.11.

5.03: Replace by "NITROGEN FIXING PLANT", and in comments: "GUILT BY ASSOCIATION WITH FAST GROWING PLANT MODIFYING THE SOIL ENVIRONMENT".
Changed to nitrogen fixing woody plant, Q5.03, but not broadened to include all legumes.

5.04: Delete entirely.
Done.

5.05: Becomes new 5.04: insert "with RHIZOMES, tubers, corms or bulbs)".
Geophyte is maintained, but rhizomes added in the explanation.

6. Leave.

6.01: Change to "Evidence of REDUCED reproduction in native habitat DUE TO ENVIRONMENTAL CONSTRAINTS".
Changed and explained in the notes.

6.02 to 6.04: Leave.

6.05: Change to "NON SPECIALIZED POLLINATION".
Changed, and although not to this wording, the effect on the score would be the same.

6.06: Leave.

6.07: Ensure that this produces a negative score, i.e., the larger the number of years, the less the weed effect. This may already be the case, but I have not checked.
Done.

7. Leave.

7.01 to 7.03: Leave.

7.04: Change last sentence in comments to "THIS INCLUDES tumbling plants".
Comments changed.

7.05: Leave.

7.06: In comments "ANSWER YES ONLY IF APPLICABLE TO NEW ZEALAND BIRDS, I.E. ONLY IF SEED UNDER 2.0 CM DIAMETER".
Done.

7.07: "... by other animals EXTERNALLY", and in comments "WITH REFERENCE TO ANIMALS PRESENT IN NEW ZEALAND, INCLUDING POSSUMS, RATS, ETC.".
Done.

7.08: "Propagules DISPERSED AFTER PASSAGE through the gut".
Made clear in explanation.

7.09: Delete entire item.
Done.

8. Leave.

8.01: Change comments: "More than 1000 viable seeds per square metre of horizontal plant area PER YEAR".
Done.

8.02: In comments: "... in the soil OR ON THE PLANT, 2 years after ...".
Noted in comments, but not changed from 1 to 2 years.

8.03: Leave.

Insert new 8.04: "DROUGHT TOLERANT", and in comments "Capable of tolerating severe seasonal droughts".
No new questions have been added.

8.04: Now 8.05: "Tolerates or benefits from DISTURBANCE or cultivation"; in comments add "DISTURBANCE INCLUDES FIRE, CLEARING, CULTIVATION, ETC.".
Done.

8.05: Now 8.06: Change to: "PLANT FREE OF natural enemies in NEW ZEALAND", in comments: "YES

RESPONSE ONLY IF EFFECTIVE ENEMIES OF THIS PLANT KNOWN FROM OTHER COUNTRIES ARE NOT PRESENT IN NEW ZEALAND.

Made clear in the notes.

PART 2: THE RISK ASSESSMENT MANUAL

1. Overview

The Weed Risk Assessment (WRA) system is a computer-based application which requires Microsoft Excel ver. 5 to run, on a PC or Macintosh computer. The computer-based system should be sufficiently well documented and intuitive to run on its own, but a complete description of the system can be provided on paper with all the guidelines and assistance necessary to allow an assessment to be made without a computer. Forms A and B are organised so that a paper-based assessment can be done, with reference to the guidelines below.

The computer-based system consists of two worksheets, the assessment worksheet (RA) and the species worksheet. The assessment sheet contains the questions to be answered for an individual species. Responses to the questions are used to generate a numerical score which is then used to determine an outcome: *accept, reject*, or *evaluate*.

The species sheet is used to maintain a record of responses for all species assessed by the system. The responses can be modified and/or re-analysed if the scoring system is modified. In principle, this list could constitute the entire list of assessed species, including those already subject to quarantine proclamations.

The system is fully automated and self-maintained, driven by buttons in the top left corner of each screen. Alternately a risk assessment can be done by keying the responses directly into the response column of the RA sheet, or filling in forms A and B and calculating the score manually.

2. Scoring

Most of the responses are translated into a numerical score, positively correlated to weed potential. In the computer-based system the scoring table is defined in the yellow columns of the Risk Assessment sheet under the heading 'Response'. The scoring table is also shown in Form B.

A typical score for a question is:

1 *Yes;* -1 or 0 *No;* 0 *Don't Know*

The 'climate' and 'weed elsewhere' sections generate a score using a weighting system: a better climate match increases the climate weight, and a poorer quality of data to attempt a match also increases the weight because of the greater uncertainty and, therefore, risk.

The 'weed elsewhere' responses, as defined in the Response column, are multiplied by the climate weight to generate the final score for each question. The weight look-up table can be modified.

The total score is compared to the critical values in the Tolerance settings table to determine the outcome. In addition to the score, the number of questions answered in each section is tallied. More information is required if the minimum criterion in the 'Questions answered' table are not met.

While the system is still being evaluated, the scoring criteria in the yellow regions can be modified to optimise the system. This includes the critical scores which determine the three outcomes. When placed in the 'protect' mode, the scoring criteria cannot be altered.

3. Computer- based WRA (and NZWRA) controls

Risk assessment sheet buttons

Protect Toggle to protect and unprotect the system. The password must be specified to unprotect. Protected sheets can be altered only in the yellow areas.

Run Run the dialogue-driven risk assessment. Alternately, the responses may be entered manually.

Get Transfer responses for a specified species from the Species sheet to the RA sheet. New species can be added to the list.

Store Transfer the current responses in the RA sheet to the Species sheet. Note that this does not save results to disk (see Save).

Species Go to the Species worksheet.

Save Save the current state of the system to disk.

Update Re-assess all the species in the Species sheet unattended - in the event that the scoring criteria have been modified.

Print Report Create a report of the assessment and print it on the currently selected printer.

Help Information on the operation of the system.

Species sheet buttons

Get	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	Sort the species sheet by botanical name.
RA	Go to the RA sheet.
Save	Save the current state of the system to disk.
Help	Information on the operation of the system.

4. Guidelines for answering NZWRA questions

BIOGEOGRAPHY / HISTORICAL

1. Domestication / cultivation

1.01 *Is the species highly domesticated?*
The taxon must have been grown deliberately and subjected to substantial human selection for at least 20 generations.

1.02 *Has the species become naturalised where grown?*
This question modifies the effect of 1.01.

1.03 *Does the species have weedy races?*
This question modifies the effect of 1.01. This is particularly to deal with registered varieties under assessment.

2. Climate and distribution

2.01 *Species suited to New Zealand climates (0-low; 1-intermediate; 2-high)*
This applies to any one New Zealand climate, or more than one. Ideally, climate matching is based on an approved system such as *Climex* or *Climate*. Such data will generally not be available in New Zealand, in which case the maximum score (2) is assigned.

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

The quality is an estimate of how complete the data used to generate the climate analysis is. If not available then assign the maximum score (2). This will generally be the case in New Zealand.

2.03 *Broad climate suitability (environmental versatility)*
Output from the climate-matching program can be used to answer here, otherwise the response should be based on natural occurrence in 3 or more distinct climate categories, as defined by Koppen or Walter. The answer to this question will be 'no' if the species is suited to a narrow range of New Zealand climates (e.g., many semi-tropical species).

2.04 *Native or naturalised in regions with equable climates*

Plants from mild equable climates are better adapted to New Zealand's climates than those from continental and tropical climates.

2.05 *Does the species have a history of repeated introductions outside its natural range?*
Should be well documented. A potential weed must have opportunities to show its potential.

3. Weed elsewhere

3.01 *Naturalised beyond native range*
Cited in floras of localities which are clearly outside the native range. If the native range is uncertain and the known extent of naturally growing plants is within the area of uncertainty then the answer is 'Don't know'.

3.02 *Garden/amenity/disturbance weed*
Plant is subject to control measures in the context given (carries less weight than 3.03). If the type of weed is uncertain, then the 'yes' response should be placed here for minor weeds, particularly if the distribution is limited.

3.03 *Agriculture/forestry/horticultural weed*
Agriculture incurs a cost from control of the plant or productivity losses. This carries more weight than 3.02. If the type of weed is uncertain, then the 'yes' response should be placed here for major weeds, particularly if widespread.

3.04 *Environmental weed*
The plant is believed to alter the structure or function of natural ecosystems, and there is documented evidence of it being controlled for these reasons. Such evidence is often in unpublished literature.

3.05 *Congeneric weed*
One or more species within the genus are well documented serious weeds.

BIOLOGY / ECOLOGY

4. Undesirable traits

4.01 *Produces spines, thorns, or burrs*
In this context, any structure known to cause fouling, discomfort, or pain to animals or humans applies. If the taxon is a thornless variety or cultivar, then there must be good evidence that it does not retain the capacity to revert to a thorny form.

4.02 *Allelopathic*
Well documented as a potential suppressor of the growth of other species. In fact, such evidence is rare from throughout the whole plant kingdom.

4.03 *Parasitic*
The parasite must have a detrimental effect on the host, and the potential hosts must be present in New Zealand. Such plants are rare.

4.04 *Unpalatable to grazing animals*
This should be considered with respect to where the plant is likely to grow and the potential herbivores present.

4.05 *Toxic to animals*
There must be a reasonable likelihood that the toxic principle will reach the animal, by grazing or contact. Many species are unpalatable, and would not apply. Some species are mildly toxic but very palatable, so could cause problems if heavily grazed.

4.06 *Host for recognised pests and pathogens*
The main concerns are hosts of toxic pathogens and alternate hosts of crop pathogens. A reasonable level of specificity should be applied; a pathogen of an entire family, such as takeall, should not be the basis for answering 'yes' to an individual.

4.07 *Causes allergies or is otherwise toxic to humans*
Must be well documented and likely to occur under normal circumstances, e.g., body contact or inhalation in the vicinity of the species.

4.08 *Creates a fire hazard in natural ecosystems*
Should be specifically applied to the situation of species growing in natural or unmanaged ecosystems, which have a documented growth habit that leads to the rapid accumulation of fuel for fires.

4.09 *Is a shade-tolerant plant at some stage of its life cycle*
Shade tolerance can enhance the invasive potential of a species.

4.10 *Tolerates a wide range of soil conditions*
New Zealand soils are generally rather infertile by world standards, but habitats susceptible to weed

invasions have a wide range of soil conditions. Species which are known to tolerate a wide range of soil nutrient levels could potentially grow well here.

4.11 *Climbing or smothering growth habit*
Fast-growing vines which are known to cover and kill or suppress the growth of the supporting vegetation. Plants which rapidly produce large rosettes or other growth forms could also apply.

4.12 *Forms dense thickets*
The thickets should obstruct passage or access, or exclude other species. Woody perennials are the most likely candidates.

5. Plant type

5.01 *Aquatic*
Any plants which are 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.

5.02 *Grass*
A large proportion of the grass family 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.

5.03 *Nitrogen-fixing woody plant*
A large proportion of woody legumes and other nitrogen-fixing plants are weeds, particularly of conservation. As with congeneric weed species, there is a high probability that a species with this ability be weeds.

5.04 *Geophyte*
Perennial with tubers, corms, bulbs, or thickened rhizomes. This question is specifically to deal with plants that have specialised organs, and should not include plants merely with creeping stems. Plants from this group can be particularly difficult to eradicate from a site.

6. Reproduction

6.01 *Evidence of substantial reproductive failure in native habitat*
Predators and other factors present in the native habitat can cause substantial reductions in reproductive capacity. When grown in areas without these factors, the reproductive output may be greatly increased.

6.02 *Produces viable seed*
If the taxon is a subspecies, it must be indisputably sterile.

6.03 *Hybridises naturally*

Documented evidence of interspecific hybrids occurring, without assistance, under natural conditions.

6.04 *Self-compatible or apomictic*
A species capable of apomixis could spread from seed produced by an isolated plant.

6.05 *Requires specialist pollinators*
Some species may require specialist pollinating agents which are absent or rare in New Zealand.

6.06 *Reproduction by vegetative fragmentation*
The plant must be capable of increasing its numbers by vegetative means to qualify, e.g., rhizome, stolon, or root fragments, suckers.

6.07 *Minimum generative time (years)*
Time from germination to production of viable seed, or the time taken for a vegetatively reproduced plant to duplicate itself. The shorter the time span, the more weedy a plant is likely to be.

7. Dispersal

7.01 *Propagules likely to be dispersed unintentionally (plants growing in heavily trafficked areas)*
Unintentional dispersal resulting from human activity; plants growing in heavily trafficked areas such as farm paddocks or roadsides.

7.02 *Propagules dispersed intentionally by people*
The plant has properties which makes it attractive or desirable, such as an edible fruit, or ornamental or curiosity value, and is readily collected as a cutting or seed. Most horticultural plants are included here.

7.03 *Propagules likely to disperse as a produce contaminant*
'Produce' is the economic output from any agricultural, forestry, or horticultural activity.

7.04 *Propagules adapted to wind dispersal*
There should be documented evidence that wind significantly increases the dispersal range of the propagule. This includes dispersal by tumbling plants.

7.05 *Propagules buoyant*
Includes any structure containing the propagule (such as a pod) which typically becomes detached from the plant and is buoyant. This does not include seeds which are carried amongst other debris in the water column.

7.06 *Propagules bird dispersed*
Any fruit which is transportable and consumed by birds. In New Zealand, this will be limited to fruits smaller than 2 cm diameter .

7.07 *Propagules dispersed by other animals (externally)*
The plant has adaptations such as burrs, and/or grows in situations which make it likely that propagules become temporarily attached to the animal. This includes rodents and marsupials.

7.08 *Propagules survive passage through the gut*
The propagule are eaten by animals, dispersed, and germinate after defecation.

8. Persistence attributes

8.01 *Prolific seed production (>1000/m^2)*
The criteria must be met under natural conditions and the number applies to viable seed. An estimate can be made from the seed output per plant and the average size of the plant.

8.02 *Evidence that a persistent propagule bank is formed (>1 yr)*
This is to identify propagules which can persist to a second season. More than 1% of the seed should remain viable beyond one year. Both canopy and soil seed banks are included.

8.03 *Well controlled by herbicides*
Well documented evidence for good chemical control of the plant, which is acceptable in the situations it is likely to be found, i.e., the chemical management should be safe for other desirable plants which are likely to be present.

8.04 *Tolerates or benefits from mutilation, cultivation, or fire*
Growth and spread of plants which can reproduce vegetatively can be enhanced by such disturbance. This should not be applied to seed banks.

8.05 *Effective natural enemies present in New Zealand*
A 'yes' response only if effective enemies of this plant, known from other countries, are also present in New Zealand. The answer is 'Don't know' unless at least one specific enemy is known.