Discussion Paper:

International Workshop on Weed Risk Assessment

for Quarantine and Coordinated Control

John Virtue[1], Dane Panetta[2], John Randall[3] and Tom Parnell[4]

[1]Animal and Plant Control Commission, Primary Industries and Resources South Australia, GPO Box 1671 Adelaide SA 5001 Australia

[2]Alan Fletcher Research Station, Queensland Department of Natural Resources, PO Box 36, Sherwood Q 4075 Australia

[3]MAF Regulatory Authority, Ministry of Agriculture and Forestry, PO Box 2526 Wellington New Zealand

[4]Australian Quarantine and Inspection Service, Department of Primary Industries and Energy, GPO Box 858 Canberra ACT 2601 Australia

Go to Weed Science

Go to the Expression of Interest Form for the Workshop

1. Workshop objective

The objective of this workshop is to develop risk assessment measures to assist in:

- deciding which species should appear on national inclusion/exclusion lists
- deciding which new weed incursions warrant coordinated control

2. Aim of this paper

The purpose of this paper is to provide the background for workshop discussions, specifically highlighting the issues that need to be considered.

3. Background: The Australian and New Zealand Contexts

About 2000 species, or 15% of the total Australian vascular flora, has been introduced, although the percentage of the introduced component of the flora varies considerably between regions. Weeds have had major impacts upon Australiaís natural and semi-natural environments, intensive agriculture and forestry. They have been estimated to cost Australian agriculture over $3.3 billion per annum, in lost production and control costs (Combellack 1989). Weeds also cause substantial degradation to the natural environment, degradation that is difficult to cost.

New Zealand has over 20 000 species of introduced terrestrial and freshwater plants, of which about 2000 have so far become naturalised. By comparison, New Zealand has only 2700 native vascular plant species. In addition to their considerable negative impacts upon agricultural and forestry production, naturalised plants pose a significant threat to natural ecosystems. A 1995 study by the New Zealand Department of Conservation identified 217 significant weeds of natural ecosystems, and more species are continually being added to this list. Collectively, these weeds have invaded all of New Zealandís native community types, in both terrestrial and freshwater environments and almost the full range of altitude, soil type, rainfall and temperature. Weed invasions are a particular threat to lowland and coastal communities that have already been stressed and fragmented by human development. However, even large, relatively undisturbed forests are being invaded by a number of species.

The rate of new invasions

A recent survey of plants naturalised in Australia found that at least 250 species became naturalised in Australia over the past 25 years, and that there was a trend for an increasing number of naturalisations in the last 15 years (Nairn *et al.* 1996). However, since many of the species recorded as naturalised during 1971-1995 may have been introduced before 1970, the apparent rate of increase in the rate of naturalisation may not necessarily be directly related to the number of species introduced and established during this period.

The 1996 survey ascribed a means of introduction for all except 20% of the total number of species naturalised. Where the means of introduction was known, most species had been introduced deliberately, as ornamental plants for horticulture (65%) or for agricultural purposes (7%). Only 2% of the naturalised species entered the country as seed contaminants (Nairn *et al.* 1996). Groves (1986) suggested that of the plants becoming naturalised in Australia, 20-40% would become weeds [cf related estimates made by Lodge (1993) (2-40%) and Williamson and Fitter (1996) (5-20%)].

In New Zealand, the number of naturalised plant pests has been steadily growing since the 1860s and this trend shows no sign of slowing. In the Auckland region alone, about four new species naturalise every year (Esler 1988). Based on historical averages, New Zealand can expect 10% of naturalised plants to become significant weeds of natural ecosystems.

Exporting invasive species

All too often the focus on invasive species is directed towards minimising their importation. As has been discussed above, importation of new species has occurred, and continues to occur, at relatively high levels. However, one musnít lose sight of the fact that certain native species from both New Zealand and Australia have been highly invasive when introduced elsewhere (Carr *et al.* 1992, Cronk and Fuller 1995). The homogenisation of the earthís flora is indeed a global problem and there is an urgent need for countries to make an attempt to minimise their *exportation as well as importation* of potentially invasive species.

4. The need for robust identification procedures

a) International political and legal frameworks

The use of measures to restrict the movement of "weed" plants, both into and within nations, due to the quarantine risks they pose, must conform with relevant international treaties. One of the agreements that establishes the World Trade Organisation (WTO) is the Agreement on the Application of Sanitary and Phytosanitary Measures (the SPS agreement). This agreement includes measures to protect human, animal or plant life/health from risks arising from quarantine pests (WTO 1994). The SPS agreement fully supports the International Plant Protection Convention of 1951 (IPPC), which deals specifically with plant quarantine issues. The agreed international definitions for a "quarantine pest" and related terms are published by the Food and Agriculture Organisation (FAO 1990) and these appear below.

The SPS agreement 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 best placed to coordinate phytosanitary standards development (WTO 1994). The standard "Guidelines for pest risk analysis" (FAO 1996) is relevant to this discussion.

The two options for implementing quarantine controls are inclusion (i.e. permitting entry to useful, non-invasive organisms) and exclusion (prohibition of harmful organisms). In general, weed quarantine is implemented using exclusion, i.e. prohibited weed lists. This "innocent until proved guilty" approach is not fail safe, as it requires weeds to be identified prior to an application to import. Comprehensive application of the alternative approach (inclusion) would require all contaminants of imported goods (e.g. grains) to be identified and assessed not to be a risk. This "guilty until proved innocent" approach has the potential to be unnecessarily restrictive on trade.

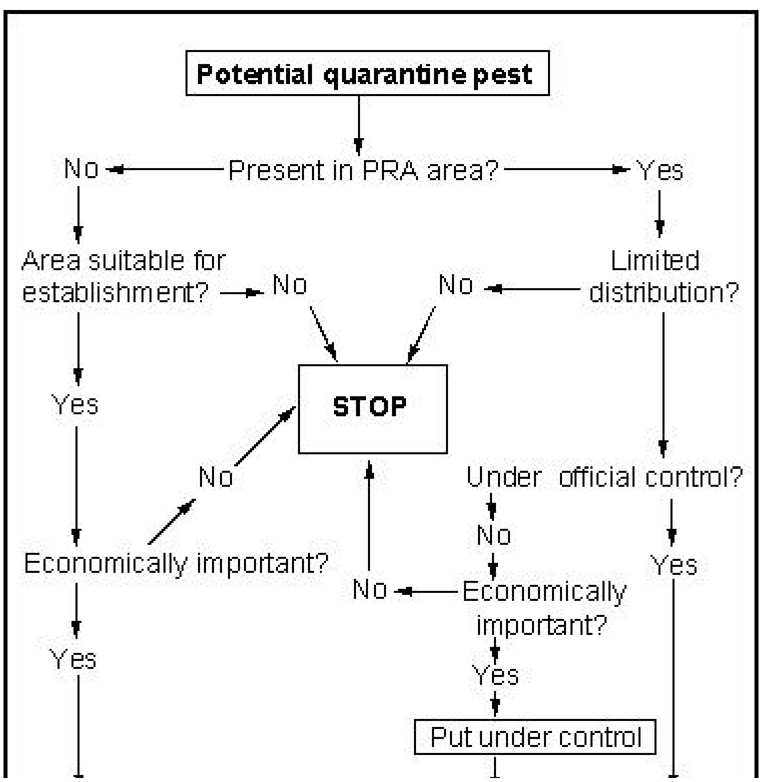

Figure 1. Assessing the Quarantine Pest Risk **-** Stage 2 of the FAO draft PRA standard (FAO 1995).

A flow chart (Figure 1), extracted from a pest risk analysis (PRA) standard (FAO 1996), demonstrates the criteria used in determining whether an organism should be assessed as a potential quarantine pest. The first significant question is presence or absence in the country or area of interest (geographic criteria).

If a taxon is already present in the country then it can only be further evaluated if it is of limited distribution and under official control (regulatory criteria). There is no quarantine justification in preventing further entry of the same taxon if it is already widespread, unless the new entry is clearly different in weed risk status from the plants already found. An example of this would be the importation of a fertile specimen of what had been a sterile species. If the species is found in a limited area, but is not under official control, then further introduction of the species can not be prevented.

If a taxon meets the geographic and regulatory criteria, an economic assessment is required. The PRA standard recognises that professional judgment is required in this process.

If the pest is not present, or is present and under official control, and could become established and be of economic importance once established, the risk of it entering the country should be evaluated. Evaluating the introduction potential of plant species requires assessment of all potential pathways of introduction. In the case of a proposed plant importation, introduction potential is considered 100%. Where there is a significant risk of introducing a weed species as a contaminant through trade, i.e. bulk grain imports, the National Plant Protection Organisation (NPPO) is justified in implementing risk management practices, provided these are shown to be the least restrictive necessary.

b) National border controls: The New Zealand example

New Zealand is an island country and, as such, enjoys the benefits of effective, natural quarantine barriers. However, it is a trading country that imports a wide range of produce from a large number of countries, from all parts of the world, which places a continual threat on its plant health status. In order that trade can continue without jeopardising New Zealand's plant health status, an integrated agricultural security system, ranging from offshore treatment to exotic pest response, has been developed.

The components of the integrated New Zealand agricultural security system are:

- International agreements/standards for phytosanitary measures
- New Zealand import health standards
- Supply country's export certification systems
- Border inspection
- Biosecurity clearance
- Plant pest surveillance
- Exotic disease and pest response

As well as the International Plant Protection Convention (IPPC) requirements, New Zealand has an obligation to comply with the conditions/requirements of the GATT Agreement on the Application of Sanitary and Phytosanitary Measures (GATT SPS Agreement). These measures essentially reinforce the requirements of the

IPPC, in that any phytosanitary measures must be transparent, technically justified and sufficient only to protect plant health (as opposed to protecting a domestic market). The process by which New Zealand MAF develops import health standards on a country:crop basis ensures that its phytosanitary measures are completely transparent.

Where possible New Zealand's phytosanitary measures, as specified in the import health standards, are based on the international standards for phytosanitary measures (ISPM). Where international standards do not exist, New Zealand (MAF) has developed its own, based on the IPPC and GATT SPS Agreement.

In the New Zealand MAF Import Health Standard system, organisms are categorised and phytosanitary measures developed accordingly. As the category (quarantine or non-quarantine) that a pest falls into will determine the risk management procedures to be adopted, it is necessary that a transparent and technically justified pest risk analysis procedure be utilised. New Zealand currently bases its PRA procedure on the ISPM: Guidelines for Pest Risk Analysis (FAO 1996) and has developed procedural documents governing this process.

5. What is missing or ineffective?

a) Quarantine considerations

The current system allows the importation of further plant material of a species to be prohibited only if the species is under official control. Almost none of the well established, known weeds of natural ecosystems would meet this criterion, as although they may be recognised threats and are being controlled on high priority sites, their eradication or containment on a national basis would be either technically impossible or financially prohibitive.

Nevertheless, the introduction of new plant material could still greatly increase the impacts of some of these species. For example:

- Crack willow (*Salix fragilis*) does not set seed in New Zealand since all plants originally introduced were males. The introduction of female plants would greatly increase the invasiveness of a species already known to be a major threat to native wetland and riparian communities.
- The native range of some weed species covers many bioclimatic zones, so different populations may have evolved different tolerances to environmental variables. These varieties may then be capable of increasing the speciesí potential geographic range, range of habitats it could invade, or rate of spread. For example, different populations of old manís beard (*Clematis vitalba*) and blackberry (*Rubus fruticosus* agg.) in New Zealand are known to have been introduced from multiple stocks from different parts of Europe, and may behave differently from each other where introduced.

Issues

- Is a fail safe system possible/necessary?
- Assessment against criteria in quarantine pest definition: What constitutes "official control" of weeds? How is "limited distribution" determined for weeds?
- Is the quarantine pest definition appropriate when there is certainty that the weed will enter the country?
- How does potential ecological impact relate to the impact (i.e. economic) specified in the definition of quarantine pest?
- Should contamination of other imports by seed be treated differently?
- How can the exportation of invasive species be minimised?

b) Prioritising incursions for coordinated control

When an invasive species has become established, long term economic and ecological benefits may be obtained by its early detection and treatment in a coordinated manner (Hobbs and Humphries 1995). However, given the existence of a large number of species that may be in the early stages of invasion and perennially limited resources, there is a need for a systematic approach to determining priorities for coordinated control.

Qualitative differences exist between the decision-making process concerning introduction of species and that concerning selection of species for coordinated control efforts. The quarantine decision will be made on the basis of a predicted negative impact, in combination with an estimate of the area over which that impact might accrue. Similar considerations will be made in prioritising incursions for control, with the difference that the ease of treatment and the likelihood of success become important additional factors (Hobbs and Humphries 1995, Hiebert 1997).

In addition to the total area over which the species has been naturalised, the feasibility of control will be related to biological and ecological features of the plant. Such features include seed dormancy/longevity, age of first reproduction, and dispersal characteristics (Dodd 1990, Hiebert 1997). Eradication programs can be very costly; in strictly economic terms, the cost of an eradication program should not exceed the current and future losses caused by the weed (Auld and Tisdell 1986).

Where no information is available about a speciesí behaviour when introduced outside its native range, quarantine decisions must be based upon information which may or may not be closely related to its invasiveness and potential impact (Reichard and Hamilton 1997). For recent incursions, plants have at least successfully passed through an environmental "filter" (Panetta 1987). Direct observations can be made *in situ* upon aspects such as plant population dynamics, dispersal ecology and, if the invasion is relatively advanced on a local scale, impact upon particular land uses or ecosystem composition, structure and function.

Where invasions are not at an advanced stage, predicting impact may be problematic. Just as it is unclear how best to go about assessing the potential invasiveness of a plant during a post-entry evaluation stage (Lonsdale 1996, Panetta 1996), or even whether such an objective is achievable (Crawley 1996, Kareiva *et al.* 1996), the same uncertainty applies to the assessment of potential impact for newly naturalised species.

Issues

- Can meaningful estimates of potential impact be made while incursions are in their very early stages?
- What biological/ecological characteristics should be considered in estimating potential impact?
- To what extent can impact in one ecosystem be generalised to other ecosystem types?
- Should extensiveness of threatened habitats be a determining factor in prioritisation for co-ordinated control?

6. Criteria that must be met by evaluation systems

Systems need to:

- be technically robust;
- contain measures that can, in general, be capable of being used by several countries, or, if not, are able to be customised;
- highlight particular risk issues that may be unique to a given country;
- be precautionary (given the many unknowns that must be addressed in a cost/benefit analysis).

An evaluation system for new incursions should distinguish between widespread species, for which control on high priority sites may be all that is feasible, and those species for which containment or eradication on a national basis is still technically and financially feasible.

A system should be flexible enough to enable widespread use, yet sufficiently robust that results can be assessed with confidence amongst agencies responsible for undertaking assessments.

7. Potential assessment criteria

a) Invasiveness

The invasiveness of a weed can be considered as its rate of spread in a specific ecosystem. For newly naturalised and invading species, the faster the rate of spread, the higher the priority for eradication or containment.

There are difficulties in measuring the actual rate of spread however:

- defining population margins is difficult;
- measurements must be long-term; and
- range expansion is subject to annual variations in climate.

In addition, measuring the actual rate of spread is not an appropriate risk assessment measure for possible additions to national exclusion lists. Thus researchers have instead identified factors that relate to the *likely* invasiveness of a plant species (Table 1).

Table 1 Factors favouring invasiveness of exotic plant species.

Factor	**References**
History as a weed elsewhere	Woody weeds in Australia (Mulvaney 1991). Noxious weeds in Australia (Panetta 1993). Weeds of southern African origin in Australia (Scott and Panetta 1993). Weeds of natural ecosystems in New Zealand (Department of Conservation, 1996). Woody weeds in North America (Reichard and Hamilton 1997).
Foci number and spacing	Simulations by Auld and Coote (1980) showed that, for an equal total area, a scattered initial population had a greater rate of spread than a single, concentrated population.
Disseminule pressure	Woody species planted more frequently are more likely to be invasive (Mulvaney 1991). Richardson *et. al.* (1994) considered the total area and the boundary:total area ratio of *Pinus* plantings as major factors in their invasiveness.
Time since naturalisation	Mulvaney (1991) and Scott and Panetta (1993) found increased time since introduction and establishment increased the likelihood of a plant becoming an invasive weed. Historical reviews of weed invasions have suggested that there is an initial lag phase of minimal spread, afterwhich a rapid, exponential expansion in range occurs (Groves 1992).

Ecological and biological attributes of plant species

Such attributes relate to mechanisms of reproduction (sexual and vegetative), seed dormancy, competitive growth habits, and efficient dispersal of disseminules (Groves 1986). Greater precision in predicting invasive species has been achieved by focusing on a group of related species in an ecosystem with a defined disturbance regime. Richardson *et. al.* (1990) identified the key attributes of a short juvenile period, relatively poor fire tolerance, strong serotiny and small seeds for Pinus invasion in South African mountain fynbos. Rejmanek and Richardson (1996) recently refined this approach with *Pinus* invasiveness being a discriminant function of, $\sqrt{\text{mean seed mass}}$, $\sqrt{\text{minimum juvenile period}}$ and mean interval between large seed crops.

Some of these attributes will be more applicable in one country than another. For example, poor fire tolerance and strong serotiny are more applicable to Australia than they would be to New Zealand.

Attributes for dispersal by humans are of high importance. Forcella (1985) observed that spread rate was faster where a weed had more agents of spread. Timmins and Williams (1987) showed the importance of the dumping of horticultural and garden waste. Panetta and Scanlan (1995) showed that humans contributed to the spread of 90% of Australian, non-native, noxious weeds.

Wide native distribution

In many cases, the sizes of speciesí geographic ranges and their average local abundances are positively correlated (Holt *et.al* 1997). Within a genus the more important weeds may have a wider native distribution. Evidence for this has been shown for *Carduus*, *Centaurea* and *Onopordum* (Forcella and Wood 1984), *Bromus* (Roy *et. al.* 1991) and *Echium* (Forcella *et. al.* 1986). This is not always true however: *Pinus contorta* is one of the most invasive pine species in New Zealand, but has a limited native distribution.

Homoclimes

Groves (1986) identified species from similar homoclimes as potential invasive weeds. However, many species have distributions that span regions of several different climate types. This may be due to life form, phenology, plasticity or ecotypic differentiation. For such species only the extremes in climate may limit their distribution (Roy *et. al.* 1991).

Taxonomic position

The notion of weedy families or genera was challenged by Scott and Panetta (1993) in their weediness analysis of southern African species naturalised in Australia. The supposedly weedy families Asteraceae and Brassicaceae were actually just large families and did not contain a higher proportion of invasive species.

Absence of natural enemies

The absence of natural enemies may promote dominance in a community rather than abiotic or management influences (Cousens and Mortimer 1995).

Genetic variation	High levels of genetic variation in the founder population will improve the chances of a successful invasion. However such high levels are not vital, depending on the life-history strategy and ecological characteristics of the weed populations. (Barrett and Richardson 1986).

Many of the principles in Table 1 have been incorporated into various decision support systems to assess invasiveness. Four of these systems are:

i) Weed Risk Assessment (WRA) System **(Pheloung 1995)**

The WRA system has been developed for rapid assessment of any plant species at the quarantine level in Australia and has been adapted for New Zealand. It consists of questions on the historical, biogeographical and biological/ecological details of the candidate species. A minimum number of questions need to be answered for each of the three sections. Answers are mainly yes, no or do not know, from which a score is calculated. The score determines whether a plant is accepted for import, rejected or requires further evaluation.

Further evaluation may simply be a more intensive literature search to answer more questions, an economic cost/benefit analysis to justify the risk of entry, or post-entry experimental assessment under field conditions. A procedure for this latter assessment has not been established and requires strategic research (Panetta 1996). On current indications, however, the scope for experimental assessment does not appear large, given problems associated with the need to interfere with natural dispersal processes, difficulties of establishing meaningful experimental contexts and the logistic requirement for adequate replication in space and time (Kareiva et al. 1996). The latter authors conclude that is highly unlikely that small-scale, short-term ecological experiments would generate accurate predictions regarding invasions.

ii) Alien Plant Expert System (APES**) (Tucker and Richardson 1995)**

This system has been developed for assessing the invasive potential of alien woody plants in the South African fynbos. The system can be represented by a flow diagram with six modules: (i) a comparison of broadscale environmental conditions between the home environment of the test species and fynbos, (ii) population characteristics and habitat specialisation of the test species, (iii) species dispersal, (iv) species seed production, (v) species seed predation and (vi) species life history adaptations to fynbos fire regimes. Within each module is a series of questions. The species is either categorised here as low risk or progresses to the next module. The system is designed to identify only canopy dominant invasive species as high risk, effectively prioritising those species that pose the greatest threat to ecosystem structure and function.

iii) Biological Success Rating **(Owen *et al.* 1996)**

The Biological Success rating is one of two ratings used to assess naturalised species as weeds of conservation in New Zealand. A score (0 or 1-3) is assigned for the criteria of (i) maturation rate, (ii) seeding ability, (iii) persistence of seedbank, (iv) effectiveness of dispersal, (v) establishment/growth rate and (vi) vegetative reproduction. The total of the scores is the Biological Success rating.

iv) Hierarchical Decision Tree (HDT) **(Reichard and Hamilton 1997)**

This system was developed to evaluate woody plant introductions to North America for their invasive potential. It was based upon predictive models derived from both discriminant analysis (see also Rejmanek and Richardson 1996) and classification and regression trees.

The HDT includes a series of questions regarding evidence for invasiveness elsewhere, relatedness to other invasive species, indigeny to other parts of North America, degree of sterility, capacity for vegetative reproduction, length of juvenile period, and requirements for germination. As with the WRA (see above), outputs from the decision tree were decisions to: accept for importation, reject, or to conduct further analysis. This system had a high predictive value, although the rate of accurate prediction was lower for non-invasive, than invasive, species.

Issues

- Can the WRA system be developed for assessment of new plant releases (ornamentals, forestry, pastures, crops) *within* a country?
- Does the WRA system provide sufficient confidence to rank invasiveness of naturalised species?
- Do score-based risk assessment schemes provide an adequate assessment of the potential economic impact of weeds?
- Can the APES be readily modified to assess alien woody plants in other countries?
- Which taxonomic group × ecosystem combinations are priorities to refine assessment of naturalised species?
- Is correction for phylogenetic relationships required when comparing species in order to identify attributes of invasiveness?
- Can post-entry experimental evaluation yield meaningful predictions of invasiveness and impact?
- How can rate of spread be measured, for development and testing of models to rank invasiveness in naturalised species?
- What should be the stance on importation of a species that is likely to become invasive only in relatively small areas? Is there scope for the importation and use of potentially invasive species in climatic regions where they are not likely to create problems?

b) Impact

Naturalised species that are targeted for control programs should have a significant economic and/or ecological impact. Such data is required for benefit/cost analyses. How this is defined and estimated depends on the ecosystem under threat. For crop weeds, economic impact is typically estimated by weed density-crop yield response curves. Weed-crop growth simulation models have been developed (Kropff and van Laar 1993) but require detailed physiological data. Assessing the economic impact of weeds in grazing systems is more difficult, as the value of pasture changes with the supply of pasture and the grazing pressure throughout the year. Given a pasture yield figure, estimations of yield loss due to a weed need to take into account whether the weed is grazed, and if so then its nutritional and toxic properties. Burrs are important if they cause animal injury or lower product value (Auld and Tisdell 1986).

Ecological impact in natural ecosystems may be measured experimentally by impacts on native species (density and diversity), and ecosystem processes (e.g. nutrient cycling, fire regimes, hydological cycles, sedimentation). Auld and Tisdell (1986) suggested assessing economic impact by the continuing cost of weed removal or the cost of removal and replacement over a shorter period.

Rather than employing direct measurements of impact, weeds may instead be categorised according to their potential impact. Systems developed to assess impact include:

i) Vegetation classification according to strategies **(Grime 1974, 1977)**

Plant species were classified by their position within an equilateral triangle using the three strategies of competitiveness, stress tolerance and adaption to disturbance (ruderals). A plantís competition index was a function of its height, lateral spread (shoots and roots) and litter accumulation. Grime (1974) used seedling relative growth rate for the stress tolerance index, although it also applies to gaining a competitive advantage after disturbance (e.g. at crop establishment). Groves (1992) suggested that species classified as competitors or competitive ruderals are major weeds in agricultural ecosystems and stress-tolerant competitors are threats to natural ecosystems.

ii) Effect on System Rating **(Owen et. al. 1996)**

This is the second rating used to assess naturalised species as weeds of conservation in New Zealand. A score (0 or 1-3) is assigned for the criteria of (i and ii) capable of changing the composition or structure of a native terrestrial or aquatic community, (iii) suppresses regeneration, (iv) persistence over time, and (v) change to the fire regime. The total of the scores is the Effect on System rating.

iii) Environmental Weeds Rating Scheme **(Swarbrick 1991)**

A simple ratings scheme was suggested with five main categories (i) canopy dominant weeds, (ii) subcanopy dominant weeds, (iii) special effect weeds (eg. high visual impact, producing allergens), (iv) minor weeds and (v) ruderals. Categories could be further broken down into life forms and important attributes.

As for assessing "invasiveness", there are difficulties in assessing the impacts a weed species has on either agricultural productivity and production costs, or on the structure, functioning and species composition of native communities. Such difficulties include:

- actual impacts are relevant only to risk assessments for species already in the country;
- evaluation of impacts is usually a long-term and complex process;
- ecological impacts vary according to the community type - it may not be clear what community types a newly-arrived species will invade;
- management regimes and the degree of human-induced disturbance can influence the invasiveness, and

hence impacts, on given sites;
- by the time a speciesí impacts become apparent or have been evaluated, its national eradication or containment may be technically impossible or financially prohibitive;
- evaluating overall potential impacts must be done on a benefit/disbenefit basis - the same outcome seen as undesirable in one location can be beneficial in another (for example dune stabilisation by marram grass (*Ammophila arenaria*) can harm native plant communities, but may be essential for management reasons in other locations).

Evaluating impacts therefore requires the evaluation of traits likely to contribute to high impacts and may need to be divided into the following groupings (while acknowledging the degree of overlap that can occur between such groupings) :

1. Agricultural and horticultural weeds
2. Weeds of natural and semi-natural ecosystems

Issues

- What are the best methods of estimating the impacts of weeds in natural ecosystems?
- What are the most important measurements of ecological impact?
- How relevant is impact data collected overseas?
- What should be the relative weightings given to the ecological and economic impacts of weeds in natural ecosystems?
- What data is available on the economic cost of weeds in natural ecosystems?
- Should only potential canopy-dominant weeds be targeted for coordinated control?

c) Potential Distribution

Knowledge of the potential distribution of a species is required for assessment at both the quarantine and naturalised species level. A greater potential distribution represents a greater potential impact and greater management costs. Landholders can be alerted of the risk of weed invasion and measures can be enforced to prevent the introduction of weed propagules into such areas. Low priority can be given to areas where the weed might fail to persist, or be of little economic importance (Panetta and Dodd 1987).

Potential distribution is determined by the interactions between a plantís environmental tolerances (climate, soil) and the local disturbance regime (ecosystem/landuse). Software based on climate to predict distribution are well developed:

i) CLIMEX (CRC for Tropical Pest Management, University of Queensland, Brisbane, Australia)

CLIMEX identifies favourable climates for an organism by calculating an ecoclimatic index for localities of interest (Sutherst and Maywald 1985). The ecoclimatic index (*EI*) is calculated as the product of indices for growth, cold stress, dry stress, heat stress and wet stress. All indices are calculated weekly and averaged to give an annual value for calculation of *EI*. The weekly growth index is the product of weekly moisture, temperature and light indices (*MI*, *TI* and *LI* respectively). Each of the stress indices is calculated using a threshold parameter and a rate of accumulation of stress parameter. Parameter values are estimated by iteration from the climatic limits of the organismís known range. Data from controlled environment studies should be used only as a starting point for these values (Sutherst and Maywald 1985). CLIMEX map output is in the form of dots at weather stations, larger dots having a greater ecoclimatic index and thus being more favourable for the organism.

ii) ANUCLIM (developed from BIOCLIM) (Centre for Resource and Environment Studies, Australian National University, Canberra, Australia)

ANUCLIM generates a bioclimatic profile for a species and matches this to regions of interest. Up to 35 bioclimatic parameters can be used to generate a profile. Panetta and Mitchell (1991) used 11 climate parameters from BIOCLIM in order to predict the potential New Zealand distributions of three weed species from their present Australian distributions: (i) annual mean temperature, (ii) minimum temperature of the coldest month, (iii) maximum temperature of the hottest month, (iv) annual temperature range, (v) mean temperature of the wettest quarter, (vi) mean temperature of the driest quarter, (vii) annual precipitation, (viii) precipitation of the wettest month, (ix) precipitation of the driest month, (x) precipitation of the wettest quarter, and (xi) precipitation of the driest quarter. ANUCLIM predictions are based on climatic surfaces, and are presented as grid data rather than dots at point locations (as in CLIMEX).

iii) CLIMATE (Agriculture Western Australia)

CLIMATE is derived from CLIMEX and BIOCLIM (now ANUCLIM), and utilises worldwide point or surface climate data to generate up to 16 climate parameters. The system is much easier to use than ANUCLIM but the current version exists only in Apple Macintosh format.

There have been few formal comparisons of the predicted and actual distributions of weeds using these software programs. Comparisons are also needed between simple climate matching (BIOCLIM, CLIMATE) and the ecoclimatic index approach of CLIMEX. An important limit to such predictions is the accuracy of native range data from which the predictions are made. Consideration must be given to correct taxonomy and to ecotypic variation. Additionally, Panetta (1987) warned that a plant may have greater climatic tolerance as a weed in a new country, owing to the absence of natural enemies and competitors. It may be more appropriate to base predictions from distribution data in countries where a species is an exotic weed, rather than from its native range.

Other approaches to predicting plant distribution include generalised linear models (GLMs) and generalised additive models (GAMs). Austin et. al. (1996) derived GLMs to describe tree species richness as a function of mean annual temperature, rainfall, radiation, survey plot size, topographic position, lithology, soil nutrient level and rainfall seasonality. GAMs are an extension of GLMs with response curves (eg. species richness vs. rainfall) not being restricted to linear or curvilinear functions. The GLM and GAM approaches rely on extensive data sets of distribution (presence and absence) and associated environmental variables for the species in question. For new weeds this data must come from elsewhere and may not be readily attainable. The approach may be more useful for predicting the potential distribution of a declared noxious weed that already has numerous, mapped, widespread populations, and areas where the weed has had opportunity to spread to but has not established.

Studies using BIOCLIM (Panetta and Dodd 1987, Panetta and Mitchell 1991) indicated that factors such as the local disturbance regime and soil type could limit distribution where climate was optimal. Geographic predictions based on climate need to be overlaid with the distribution of the ecosystem/s suited to the weedís life cycle. Soil and topographic maps provide the opportunity to increase accuracy of distribution predictions, assuming there are strong relationships between weed abundance and such attributes as soil pH, drainage, water holding capacity, chemical fertility and aspect.

Issues

- How should a survey be designed to test the predictions of distribution models based upon climate (species, scale, density vs. presence/absence data)?
- What geographic scale of distribution predictions is appropriate for use by agencies controlling naturalised plants?
- Which soil and topographical attributes are major limits to weed distribution and abundance?
- How can access to worldwide distribution data (native and exotic range) be improved?

d) Cost Benefit Analysis

Cost Benefit Analysis must:

i) Consider the reversibility and substitutability of effects:

Are negative impacts essentially irreversible for technical or financial reasons? Ecological impacts are often irreversible (especially if they cause local species or community extinctions), and non-substitutable (the values, species or functioning of one community type cannot be replaced by another, or even necessarily by the same community type at another location);

ii) Recognise that time scales used in assessment must be appropriate to the systems being evaluated - impacts on native communities commonly develop over extended periods (10-20-50 years), but should not be any less important for that, compared to shorter term gains or losses in agricultural/horticultural systems.

iii) Consider the focus of costs and benefits:

Commercial gains (agricultural/horticultural) are usually captured by the landowner and are economically measurable. Costs generated by weeds of agricultural/horticultural systems accrue heavily to the landowner, but also spread to other landowners and the general public (for taxpayer-funded agency and council work).

Costs and benefits of environmental weeds both accrue to the general public, but benefits are not necessarily measurable or comparable to commercial gains.

iv) Take a precautionary approach given that:

The containment or eradication of a species once it is in the country will be extremely expensive and will rapidly become technically impossible.

The impacts of a species once it becomes established may be irreversible or non-substitutable (see above).

Issues

- How should benefits and costs be apportioned between stakeholders?
- How can long term benefits and costs best be accounted for in relation to their short term counterparts?
- Should cost thresholds exist, beyond which the introduction of a species would be prohibited, regardless of its potential benefits?
- When can the potential benefits of a species (that is also a potential weed) be gained through other management methods or through the use of other, less invasive species?

Go to Weed Science

Go to the Expression of Interest Form for the Workshop

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Attachment 1

RELEVANT PHYTOSANITARY TERMS AND DEFINITIONS

Area An **officially** defined country, part of a country or all or parts of several countries [revised, 1995]

Containment The application of **phytosanitary measures** in and around an infested **area** to prevent **spread** of a **pest** [new, 1995]

Control (of a **pest**) **Suppression**, **containment** or **eradication** of a **pest** population [new, 1995]

Endangered area An **area** where ecological factors favour the **establishment** of a **pest** whose presence in the **area** will result in economically important loss [new, 1995]

Eradication Application of **phytosanitary measures** to eliminate a **pest** from an **area** [revised, 1995; formerly **Eradicate**]

Germplasm Plants intended for use in breeding or conservation programmes

IPPC Abbreviation for the International Plant Protection Convention, as deposited in 1951 with FAO in Rome and as subsequently amended

National Plant Protection Organisation Official service established by a government to discharge the functions specified by the **IPPC** [formerly **Plant Protection Organisation (National)**]

Official Established, authorised or performed by a **National Plant Protection Organisation**

Pest Any species, strain or biotype of plant, animal, or pathogenic agent, injurious to **plants** or **plant products** [revised, 1995; definition subject to formal amendment of IPPC]

Pest risk analysis Pest risk assessment and **pest risk management** [new, 1995]

Pest risk assessment Determination of whether a **pest** is a **quarantine pest** and evaluation of its **introduction** potential [new, 1995]

Pest risk management The decision-making process of reducing the risk of **introduction** of a **quarantine pest** [new, 1995]

Phytosanitary Pertaining to **plant quarantine**

Phytosanitary measure Any **legislation**, **regulation** or **official procedure** having the purpose to prevent the **introduction** and/or **spread** of **quarantine pests** [new, 1995]

Plant product Unmanufactured material of **plant** origin (including **grain**) and those manufactured products that, by their nature or that of their processing, may create a risk for the **spread** of **pests**

Plant quarantine All activities designed to prevent the **introduction** and/or **spread** of **quarantine pests** or to ensure their **official control** [revised, 1995]

Plants Living **plants** and parts thereof, including **seeds**

PRA area Area in relation to which a **pest risk analysis** is conducted [new, 1995]

Quarantine Official confinement of **plants** or **plant products** subject to **phytosanitary regulations** for observation and research or for further **inspection, testing** and/or **treatment** [revised, 1995]

Quarantine area An **area** within which a **quarantine pest** is present and is being **officially controlled** [revised, 1995]

Quarantine pest A **pest** of potential economic importance to the **area endangered** thereby and not yet present there, or present but not widely distributed and being **officially controlled** [revised, 1995; definition subject to formal amendment of IPPC]

Spread Expansion of the geographical distribution of a **pest** within an **area** [new, 1995]

Standard Document, established by consensus and approved by a recognised body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context [new, 1995; ISO/IEC GUIDE 2:1991 definition]

Suppression The application of **phytosanitary measures** in an infested **area** to reduce **pest** populations and thereby limit **spread** [new, 1995]