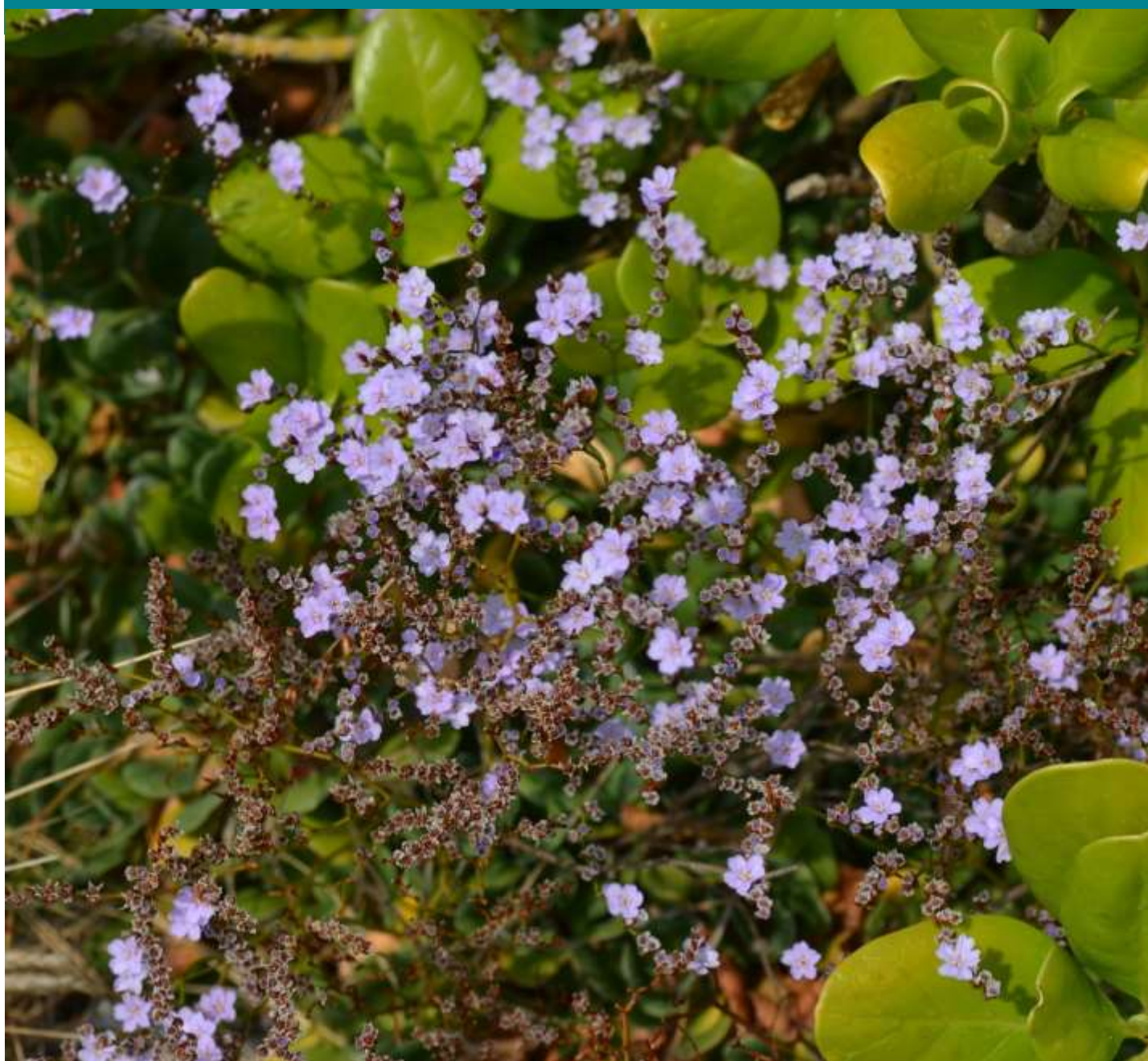


# Environmental weed risk screen for Victoria

Background and development



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## Background

In 2015 the Victorian Government commissioned the development of an environmental weed risk screen - a method designed to identify species that pose the greatest weed risk, based upon measures of (or characteristics related to) invasiveness (the 'likelihood' component of risk) and impact (the 'consequence' component of risk).

The screen was developed by Dr F. Dane Panetta, Bioinvasion Decision Support, to assess the weed risk posed by a plant that has been either newly detected, or has been known to be present for some time but not assessed previously. Its purpose is to provide a means for identifying the plants that pose the highest threat to biodiversity, particularly on public land at the local scale e.g. national park, conservation reserve, State forest (Blood, James and Panetta 2016).

The unpublished material completed in May 2015 was originally titled "Which plants should be delimited? A simple screen for the assessment of weed risk to biodiversity". It was accompanied by "A risk assessment screen for evaluating weed risk to biodiversity: user's manual". Both documents have been combined into this report to be available as a background to the screen development.

The 'user manual' component (including Appendix 1 and the score sheet template in Appendix 2) with extracts from the body of this report have been modified and incorporated into "Managing weeds: assess the risk guide. A guide for assessing the risk for weeds at the early stage of invasion on public land in Victoria" (Blood, James and Panetta 2016).

Appendix 3 contains a recommendation for Victoria on the use of a unified classification of alien species based on the magnitude of their environmental impacts.

## Summary

Some environmental weeds pose serious threats to the biodiversity values of natural areas. First detections of plant species occur relatively often at the local scale and this situation can be expected to continue. How should these species be managed? The answer depends on a number of factors, but the fundamental one is how great a threat a species represents, i.e. its weed risk. In the context of new detections, weed risk assessment (WRA) considers the probability that a plant will persist and spread (its invasiveness) and the consequences of such spread (its impact). Current WRA procedures, while thorough, are too time-consuming and costly to address the potentially large numbers of plants concerned. They are also essentially 'desktop' activities that attempt to predict how a plant will behave in the field.

A simpler WRA screen is described in this document. It has two components: 1) what is known about the behaviour of a species in other parts of Australia and elsewhere in the world (i.e. its Weed History), and 2) on-ground evidence of its invasiveness and impact where it has been detected (i.e. its Local Performance). Simple distance- and area-based measurements taken in the field are required for the latter component. Weed History and Local Performance then are combined to form a weed risk matrix.

Management options for newly detected species include eradication, containment or indefinite control to a level at which biodiversity values are not significantly impacted. Eradication is often an attractive proposition because of the prospect of a permanent solution to a problem that otherwise could exist in perpetuity. However, it may be an expensive undertaking and often success cannot be guaranteed. It is therefore advisable to determine how feasible this management strategy is, and the first step towards estimating eradication feasibility is to delimit a species, i.e. to determine its total spatial extent. The weed risk management matrix presented is used to derive a recommendation either to delimit the species (as a precursor to further determination of eradication feasibility) or to monitor it in the future in order to detect changes in its invasiveness and/or impact, should these occur. If practicable, monitoring at yearly intervals is recommended. Using the WRA screen and the associated weed risk matrix should require at most a day's effort per species.



# Introduction

Eradication is defined as the elimination of every individual of a species (for plants, including seeds) from an area in which recolonisation is unlikely to occur (Myers *et al.* 1998). Eradication may be the most cost-effective way to manage newly detected plants, but it must be a feasible management option. Eradication feasibility is a function of many factors, a key one being the amount of area that is infested (Panetta 2009). Thus, the first step in determining eradication feasibility for a potential candidate species is to ascertain its total spatial extent. This activity is known as delimitation. Once the species has been delimited, a realistic assessment of its eradication feasibility will be possible (Dodd *et al.* 2014; Panetta 2015).

Eradication is an attractive proposition because it offers the possibility of achieving a permanent solution to a looming problem. However, it may be costly to achieve, success cannot be guaranteed, and there is a risk that the scarce resources invested may turn out to have been better invested elsewhere. Over time, land managers will be confronted by many introduced plants, some of which may represent first detections in Victoria, while others may be problematic elsewhere in the state, but detected for the first time at the local scale. How does one select plants for consideration as eradication targets? The first step is assess the risk that they pose.

The process of risk assessment addresses the likelihood of a damaging event occurring (expressed as a probability) and the consequences of the event's occurrence (expressed in terms of magnitude). Negative consequences are generally known as hazards. Weed risk assessment (WRA) is a discipline that involves quantitative estimation of the likelihoods and magnitudes of hazards posed by introduced plants. In this context 'likelihood' refers to the probability that an introduced plant will be introduced, establish and spread, and 'hazards' encompass all of the negative impacts that could result as a consequence of its spread (Daehler and Virtue 2010).

Weed risk assessment may be applied before a plant has been introduced to a country or region, or it may focus on plants that are known to occur already. These procedures are referred to as pre- and post-border WRA respectively. The screen described in this document is concerned with the latter. While WRA procedures have been shown to identify potentially damaging species with a relatively high degree of success, they have not been as effective in identifying species that have been proven to be relatively benign. This difficulty arises from the so-called 'base rate effect', which in this context refers to the proportion of total introductions that will become high risk weeds. This effect can be expected to vary according to the plant group concerned (for example, very few orchid species have become invasive) but in general the base rate can be expected to be less than 10%, often considerably less. Hulme (2012) cites studies from the British Isles, Australia and New Zealand, in which pest plants comprise <2% of the total number of introduced species.

Indeed, the base rate phenomenon has been one of the reasons for challenging the accuracy of current WRA procedures. In a somewhat controversial paper, Hulme (2012) has argued that it will be difficult for these procedures to improve on predictions of weed risk that are based simply on a knowledge of prior weed history together with the quality of climate match. He maintains that under such circumstances decision-makers should invest in early detection, mitigation (i.e. actions, such as eradication, that serve to reduce exposure to risk) and management.

Of the two components of risk assessment (likelihood and consequence), it can be argued that consequence is paramount. Some plants may spread very rapidly but have very little impact. For example, many plants that are restricted to highly disturbed areas spread rapidly owing to a close association with human activity, but are not likely to impact greatly upon the values associated with the habitats that they invade. Some widespread North American forbs such as Common Groundsel (*Senecio vulgaris*), Chickweed (*Stellaria media*) and *Erodium* spp. have spread widely but are not listed on noxious or wildland weed lists (Drenovsky *et al.* 2012). On the other hand, species might spread slowly and/or episodically (e.g. trees that have a very prolonged juvenile period, or water-dispersed plants of semi-arid or arid ecosystems that spread only after rare high-rainfall events), yet cause major impacts in the long run. Some species may not spread at all, but still have substantial adverse impacts. For instance, many introduced eucalyptus species

have not been observed to invade in South Africa, but planted trees can have substantial impacts on local hydrology by virtue of their extensive root systems (J.R. Wilson, pers. comm.).

Attempts to predict invasiveness have met with more success than those concerned with impact (Pyšek *et al.* 2012). This is partly a function of the complexity of impact, which has environmental, economic and social dimensions. These dimensions may overlap, and each embodies yet further complexity. For example, weeds that impact environmental values may do so via effects upon biodiversity, disturbance regimes or ecosystem services. Another issue, which is particularly relevant to natural ecosystems, is that impact arises from an interaction between an introduced plant and the local plant community and as such is context-specific (Pyšek *et al.* 2012).

The focus of this report will be on weed risk to biodiversity impacts. There is a longstanding and widespread recognition that weeds pose a significant threat to biodiversity (Humphries *et al.* 1991; Adair and Groves 1998; Byers *et al.* 2002; Richardson and van Wilgen 2004; Roberts *et al.* 2015) and therefore need to be managed in order to protect biodiversity values. Some studies have identified thresholds in weed cover, i.e. levels of cover beyond which impacts upon the number of species and community structure become more severe (Gooden *et al.* 2009; McAlpine, Lamoureaux and Westbrooke 2015; Fried and Panetta in review). For well-established species, management that maintains weeds below such thresholds should assist in protecting biodiversity (Simberloff 2003). However, the most cost-effective means of managing the threats posed by new invaders may be to eradicate such plants, given that a number of prerequisites are met (Panetta 2009).

## Post-border weed risk assessment

The Australian post-border weed risk management protocol (Virtue *et al.* 2006) and its updated version (in preparation) stipulate that post-border weed risk assessments should address the major components of invasiveness and impacts (Table 1).

**Table 1. Criteria for invasiveness and impacts as listed in Virtue *et al.* (2006). Major *direct* impacts on biodiversity are highlighted. (Note that while impacts upon ecosystems processes are an important aspect of the overall effects of weeds on natural ecosystems, these will likely be *indirect* effects of processes that impact biodiversity directly).**

Invasiveness	Impacts
Ability to establish within existing vegetation	Reduction of establishment of desired plants
Reproductive ability (vegetative, seed, time to seeding)	Reduction of biomass/yield of desired plants
Dispersal ability (especially over long distances)	Reduction of quality of products or services
	Restriction of physical movement
	Effects on human and/or animal health
	Effects on ecosystem processes

Post-border WRA procedures, such as the one currently employed in Victoria (Weiss and Iaconis 2002), require a level of detail for invasiveness and impact criteria (Tables 2 and 3) that may not be readily available, thereby increasing both the time needed to complete an assessment and (potentially) the amount of uncertainty associated with the assessment.

**Table 2. Questions associated with the assessment of invasiveness in the Victorian WRA procedure.**

<b>Establishment</b>
<ul style="list-style-type: none"> <li>• Germination requirements?</li> <li>• Establishment requirements?</li> <li>• Disturbance requirements?</li> </ul>
<b>Growth/competitive ability</b>
<ul style="list-style-type: none"> <li>• Life form?</li> <li>• Allelopathic properties?</li> <li>• Tolerates herbivory pressure?</li> <li>• Normal growth rate?</li> <li>• Stress tolerances?</li> </ul>
<b>Reproduction</b>
<ul style="list-style-type: none"> <li>• Reproductive system?</li> <li>• Propagule production?</li> <li>• Seed longevity?</li> <li>• Reproductive period?</li> <li>• Time to reproductive maturity?</li> </ul>
<b>Dispersal</b>
<ul style="list-style-type: none"> <li>• Number of mechanisms?</li> <li>• How far do propagules disperse?</li> </ul>

**Table 3. Criteria to be addressed for the assessment of impact upon biodiversity in the Victorian WRA procedure.**

<b>Flora and Fauna</b>
<b>Vegetation</b>
Impact on the vegetation composition on the following:
<ul style="list-style-type: none"> <li>• High value ecological vegetation classes</li> <li>• Medium value ecological vegetation classes</li> <li>• Low value ecological vegetation classes</li> <li>• Structure of a vegetation community?</li> <li>• Threatened flora spp.?</li> </ul>
<b>Fauna</b>
<ul style="list-style-type: none"> <li>• Threatened fauna spp.?</li> <li>• Non-threatened fauna spp.?</li> <li>• Benefits or facilitates the establishment of indigenous fauna?</li> <li>• Toxic, its burrs or spines affect indigenous fauna?</li> <li>• Provision of habitat or food source for pest animals?</li> </ul>

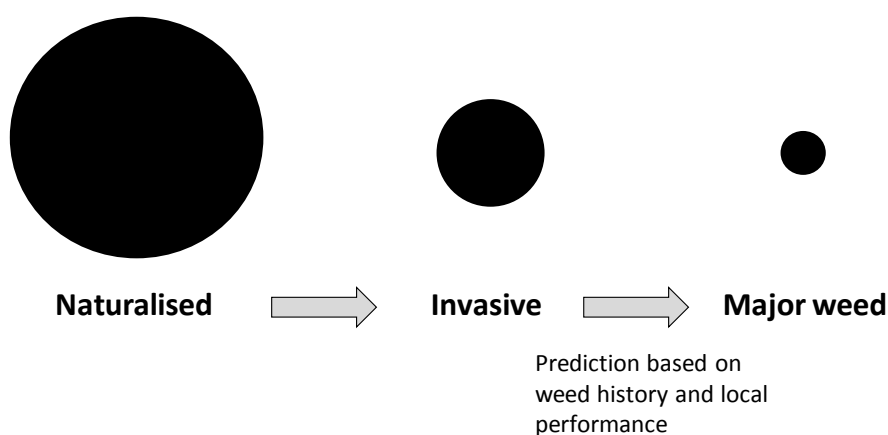


## Post-border weed risk management

Weed risk assessment in the post-border context assists in the identification of plants that pose the greatest risk. However, post-border WRA is just one component of the higher level activity that is weed risk management. Weed risk management (WRM) is a process of treating identified risks to achieve a balance between realising opportunities for gains while minimising losses (Virtue *et al.* 2006). Risk assessment and risk management are functionally separate, but interacting, risk analysis activities (Andersen *et al.* 2004). In addition to risk identification and quantification, WRM includes the activities of evaluation, selection and implementation of actions to reduce risk. It is sometimes necessary to consider risk assessment and risk management simultaneously in order to respond effectively to detections of introduced plants—the stage of invasion should dictate the appropriate response. Assessing the feasibility of management is central to WRM.

Operationally, WRM is essentially based upon decisions concerning how best to invest limited resources. Managers of natural areas are generally faced with numerous threats to natural area values and where invasive species are concerned there may be a need to allocate scarce resources across a range of organisms at various stages of invasion. Hence, there is a need for a system that will help to prioritise newly detected species in terms of the threats that they pose.

In order to become weeds, introduced plants must undergo a series of transitions (Figure 1) that represent stages that progress from doubtful persistence (i.e. casual status) to the formation of self-sustaining populations (naturalised), to actively spreading (invasive) and causing substantial damage (major weed). If the introduced plant has already naturalised (a common occurrence by the time that it has been detected), the likelihood component of the risk equation (i.e. Risk = Likelihood X Consequence) corresponds to the probability that it will spread. Once a plant has been detected there is an opportunity to use information gained from field observations to improve the assessment of weed risk. This is the basic rationale for the WRA screen developed here.



**Figure 1. Plant status post-naturalisation. Circle size is relative to the proportion of total numbers of species. Species must spread (more than 100 m in less than 50 yrs for plants spreading via recruitment from seeds and other propagules (detachable vegetative structures), and more than 6 m in 3 yrs for plants spreading via roots, rhizomes, stolons or creeping stems; Richardson *et al.* 2000) to be considered invasive and must cause large impacts to be considered major weeds. Only a small proportion of the naturalised species pool will ultimately cause substantial damage. A plant's weed risk may be assessed on the basis of both its history as a weed elsewhere and its local performance (see below).**

## Purpose and rationale for the development of the risk assessment screen

The screen described here has been designed to assess the weed risk posed by a plant that has been either newly detected, or has been known to be present for some time but not assessed previously. Its purpose is to provide a means for identifying the plants that pose the highest threat to biodiversity, thereby warranting further assessment for eradication feasibility, involving a delimitation exercise in the first instance (Figure 2).

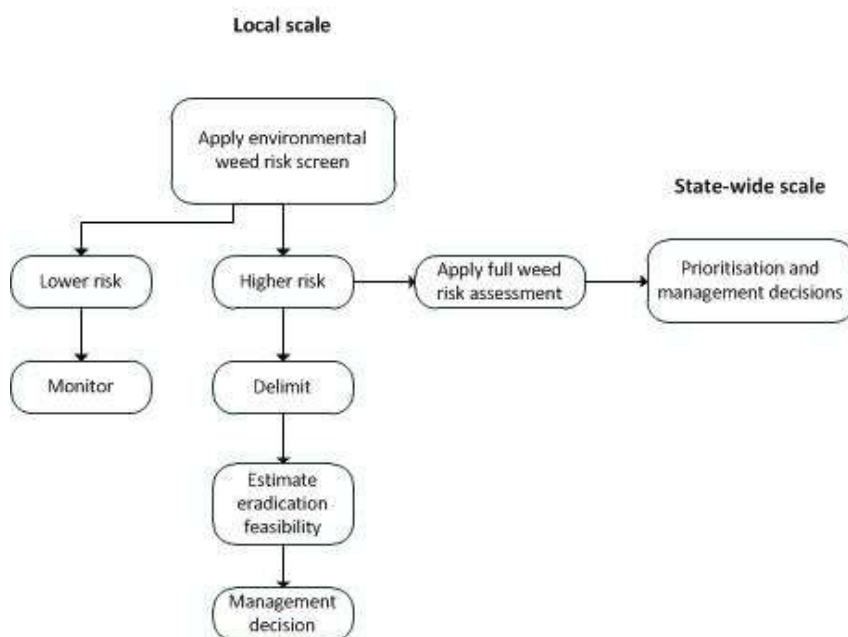


Figure 2. Place of the WRA screen in the management of post-border weed risk in Victoria. The screen is designed to support risk assessment and risk management at the local scale. In order to make decisions on a larger scale, or to address other values (in addition to biodiversity), a full WRA will be required.

As stated earlier, prior weed history, together with quality of climate match, may provide an assessment of weed risk that rivals that of current, more elaborate WRA procedures (Hulme 2012). This argument is based upon the observation that high risk weeds comprise only a small proportion of the total number of introduced plants that establish. The rationale of the present screen has its roots in this argument, but it differs in the following ways:

- 1) climate matching is not employed, owing to the need for a screen that is simple and that may be used by land managers who do not have access to, or the training required for using, climate-matching software. Instead, prior weed history is interrogated so that the number of world regions in which a species is an environmental weed can be used as a proxy for climate match;
- 2) on-ground evidence of plant spread is used to obtain direct measurements of invasiveness;
- 3) on-ground evidence of plant performance (in particular, plant cover) is used as a measure of potential impact upon biodiversity.

While the screen does not incorporate climate matching (i.e. between the area where weed risk is being assessed and the native range of the species, or regions elsewhere in the world where it is an environmental weed), the present approach may be justified by considering the likely pathways of species introduction. The major pathway of introduction for environmental weeds in Australia has been via importation and sale for ornamental use (Groves *et al.* 2005) and, to a lesser extent, for use in agriculture (see van Klinken *et al.* 2015). In the former case, the appearance of a species in a natural ecosystem

indicates sufficient climatic pre-adaptation to enable it to escape cultivation and to persist, at least in the short term. For the latter pathway, selection, importation and widespread use are all based on an assumption of climatic pre-adaptation.

## Components of the screen

The screen described below comprises two components: Weed History and Local Performance. These are assessed separately and then combined to form a Weed Risk matrix, which shows four combinations of different levels (low and high) of evidence for each of these components.

A screen score sheet template has been provided in Appendix 2 that summarises the components below and allows a user to complete the screen.

### Weed History

In this part of the screen the strength of evidence for weediness in the species is assessed. The use of online data sources, in particular the global compendium of weeds (Randall 2012), is emphasised. It is assumed that a formal identification of the plant concerned has been made. In searching for information, it is also important to determine whether synonyms for the species exist and to take care not to "double-count" sources of information that relate to both the name in use and its synonyms. Any records of 'global' location should be ignored, unless the user has access to the source and can determine where specific records are from. Records that correspond to lists of potential weeds should also be discounted, unless, again, primary sources can be accessed to determine whether these lists include actual records of occurrence.

When the species has no recorded history as a weed, some approaches have considered evidence of weediness from closely related species, specifically those in the same genus (Pheloung *et al.* 1999; Diez *et al.* 2012). However, this information needs to be adjusted for the size of the genus (Nel *et al.* 2004), since larger genera may have more weedy species by virtue of their size alone. For the purposes of the present exercise this is considered to be an unnecessary complication.

Note that the scoring system presented may also be used for new detections of *native* species, for instance native plants that have been introduced from Australian regions in which they are indigenous.

### Calibrating Weed History data

It is not easy to compare information related to weed history with the outputs from current weed risk assessment procedures because the levels of risk as assessed by the latter are based on factors additional to invasiveness and impacts. For example, both the Victorian WRA procedure and the methods used in the construction of the Weed Advisory Lists (Adair *et al.* 2008a,b; Adair *et al.* 2009a,b,c) take into account the current distribution of a candidate species in relation to its total potential distribution. Estimates of potential distribution are based upon climate matching software and, as discussed earlier, are beyond the scope of the present exercise. Furthermore, the Victorian WRA procedure takes account potential social and economic impacts, in addition to the potential environmental impacts of assessed species.

That said, the Weed Advisory Lists provide a readily accessible assessment of a large number of environmental weeds found over a range of Victorian bioregions and were therefore used as a basis for calibrating the information on weed history found in Randall (2012). Another advantage of the Weed Advisory Lists is that the impact categories as defined refer to known and documented cases of impact elsewhere (see Table 4). For the invasiveness criterion, Adair *et al.* listed three levels: HR (= high risk), R (= risky) and LR (= low risk). For the present exercise these categories were converted to H (= high risk), M (= medium risk) and L (= low risk) respectively.

Table 4. Definitions used by Adair *et al.* (2008a,b) and Adair *et al.* (2009a,b,c) for the different levels (H, M and L) for invasiveness and impact criteria. Definitions for H in both criteria are highlighted. (Note the addition of italicised information—presumably implied—in the definition relevant to invasiveness).

Criterion	
<b>a) Invasiveness</b>	
High	• Able to readily establish in native vegetation ( <i>spreads rapidly</i> )
Medium	• Limited capacity to establish in native vegetation, but either establishes with some difficulty or spreads slowly
Low	• Limited risk, low invasiveness
<b>b) Impact</b>	
High	• Species with the ability to cause acute disruption to ecological processes, dominate vegetation strata, cause severe loss of biodiversity. Rates of biomass accumulation are generally high. Multiple cases of invasion with high impact consequences known or documented.
Medium	• Species with the ability to invade native vegetation with low levels of disturbance, cause loss of biodiversity. Moderate to high rates of biomass accumulation. Cases of invasion known or the potential to cause biodiversity losses considered sufficient to require suppression.
Low	• Species naturalised in native vegetation but causing minimal disruption to ecological processes, negligible losses to biodiversity or their presence is transient only.

A calibration exercise was undertaken to determine whether species in the highest risk categories for both invasiveness and impact (i.e. species designated H,H in the Weed Advisory Lists) differed from those under all other categories in terms of a) the number of environmental weed references and b) the number of world regions in which a species was listed as an environmental weed in Randall (2012). For each of the four Victorian bioregions concerned (Ranges, Mallee, Inland plains, Coastal plains and heathy forests) a sample of 20 species was chosen at random. Half of these samples were taken from the H,H category and the other half from the combined species in the other eight categories (Table 5). There were insufficient species in the Aquatic Weed Advisory List for inclusion in this analysis.

**Table 5. Categorisation of environmental weeds in terms of invasiveness and impact criteria, according to the Weed Advisory Lists. In the present analysis, comparisons were made for each region between random samples from the high impact and high invasiveness (H,H; shaded) category and all other categories combined.**

Category		Ranges	Number of species			
			Mallee	Inland plains	Coastal plains & heathy forests	Aquatic
Invasiveness	Impact					
H	H	58	42	79	97	10
H	M	53	29	92	53	4
H	L	58	36	90	157	4
M	H	11	5	44	47	2
M	M	91	22	61	104	3
M	L	67	24	69	59	1
L	H	31	4	41	31	0
L	M	174	17	54	79	4
L	L	169	37	141	131	1
<b>Total</b>		<b>712</b>	<b>216</b>	<b>671</b>	<b>758</b>	<b>29</b>

The number of references was log-transformed to normalise data prior to performing a t-test to determine the level of significance of the difference between the mean values for both categories (i.e. H,H and the combination of all others). There was a highly significant difference ( $P = 0.00138$ ,  $df = 78$ ) between the mean value for number of references for species in the H,H category (12.9) and the mean value (8.3) for number of references in all other categories. (This means that there are only slightly more than 1 in 1000 odds that such a difference would arise by chance alone.) It should be noted, however, that this is at best a very crude measure, and is complicated by the fact that references in Randall (2012) are often not independent. For instance, more recent references may be based on earlier ones: the issue of "cascading references", as noted by Randall.

The frequency distribution of the number of world regions in which species occurred as environmental weeds was skewed—many species on the Weed Advisory Lists were found in at least one region (almost always Australasia), but relatively few were found in the highest number of regions (Figure 3). It was not possible to distinguish H,H species from the combined other categories on the basis of world distribution, since some in the latter group were documented to be weeds in either four or five world regions (Table 6). This measure is also compromised by the fact that plants that have been moved most around the world would have the greatest opportunity for demonstrating weediness. The number of world regions may nevertheless be considered a reasonable proxy for adaptation to a broad range of environmental conditions, both non-biological (e.g. climate and soils) and biological (e.g. different plant communities). The number of world regions is therefore used in the construction of the screen (see below).

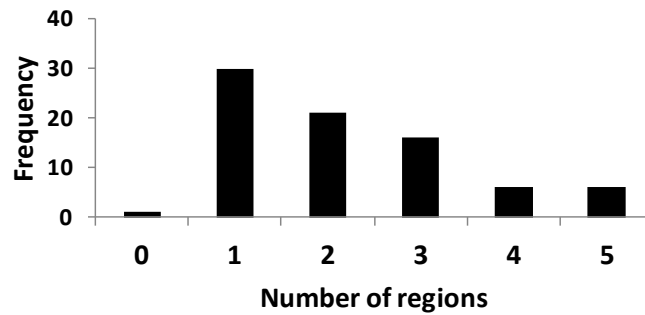


Figure 3. Number of world regions in which species sampled from the Weed Advisory Lists are documented to occur as environmental weeds, according to Randall (2012). World regions comprise Africa, Australasia (i.e. Australia and New Zealand), Caribbean, Europe, North America, Pacific, South America and Subantarctic.

Table 6. Number of world regions in which species from different Weed Advisory Lists (WAL) are found as environmental weeds, and the number of references for each species, based upon information in Randall (2012). Rankings of high (H), medium (M) and low (L) for invasiveness (inv.) and impact are from the Weed Advisory Lists for a sample ( $n = 20$ ) taken at random from each list, divided equally between high risk species (H,H; shaded) and all of the others.

No. world regions	Species	WAL ranking (inv., impact)	WAL bioregion	No. references
4	<i>Avena fatua</i>	L,M	Mallee	12
4	<i>Anthoxanthum odoratum</i>	H,H	Mallee	24
4	<i>Ligustrum sinense</i>	H,H	Coastal plains & heathy forests	39
4	<i>Hedera helix</i>	H,H	Ranges	36
4	<i>Vulpia bromoides</i>	H,H	Mallee	13
4	<i>Tamarix ramosissima</i>	H,H	Mallee	18
5	<i>Cortaderia selloana</i>	M,H	Ranges	20
5	<i>Cortaderia jubata</i>	M,H	Coastal plains & heathy forests	23
5	<i>Lonicera japonica</i>	H,H	Ranges	52
5	<i>Pittosporum undulatum</i>	H,H	Ranges	19
5	<i>Plantago lanceolata</i>	H,L	Inland plains	16
5	<i>Potentilla indica</i>	M,M	Coastal plains & heathy forests	9

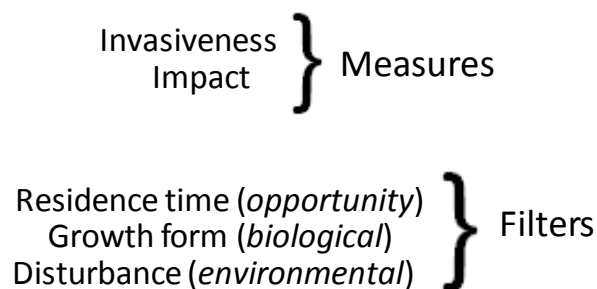
### Local Performance

This part of the screen considers factors that are related to impact and evidence of *actual* spread (as opposed to *potential* spread, which is used in both the Victorian WRA procedure and the Weed Advisory Lists). In addition to the information gathered regarding invasiveness and impacts ('the measures'), other information is sought that will assist in interpreting values for the measures ('the filters'; see Figure 4). Two of the filters (residence time and growth form) relate to the opportunity that a plant has had to increase in abundance and to spread. For residence time, the longer that a plant has been present, the more likely that it will have naturalised and spread, given that it has the inherent potential to do so. The growth form (and associated with this, how long it takes for a plant to mature and reproduce) of the plant will dictate how quickly newly established individuals can multiply. These two filters are referred to as 'time-related filters'.

The purpose of the third filter (the 'disturbance filter') is to distinguish plants that are capable of establishing, multiplying and spreading, and causing significant impact in relatively intact native vegetation from those that perform well only under highly modified conditions, such as occur at the edges of native stands, including situations where edges are created by roads and tracks. Generally, only the former group can be considered as major environmental weeds. Disturbance comes in many forms, some of which (e.g. fire, or flooding in parts of the landscape) are entirely or largely natural, and others of which are human-



mediated (e.g. clearing of natural vegetation, prescribed burning, or input of nutrients through fertilisation).



**Figure 4.** Components used in assessing Local Performance, consisting of *measures* of invasiveness and impact, and *filters*, which assist in interpreting values for the measures. Residence time and growth form are both time-related filters. Disturbance functions as a habitat filter that gives higher weight to measures of invasiveness and impact that have been obtained in intact native vegetation.

## Measures

As was noted earlier, the purpose of risk assessment (and risk management) is to identify and either avoid or reduce a hazard, which in this case is impact upon biodiversity. The primary consideration here is field observations that indicate that the species could have adverse effects upon biodiversity, both where it is found and over a wider area, should it spread.

### **M1 Invasiveness**

This component requires the user to determine whether the plant has spread vegetatively, by seed or via both mechanisms. The user is asked to make simple measurements in relation to these possibilities. It may be difficult to identify seedlings when these are isolated, but it should be possible to get some idea of seedling identity, based upon the fact that most seedlings will appear close to parent plants. Should seedlings be detected, information on the pre-reproductive period (i.e. juvenile period) of the plant will give some idea of potential rates of spread—plants with shorter life cycles will spread more quickly than those with longer life cycles, all other things being equal.

Propagules are detachable structures that can grow into new plants. These are commonly seeds, but also include detachable vegetative structures such as stem segments, bulbils, and aerial tubers. Vegetative reproduction can occur via such detachable structures, but more commonly occurs via connected vegetative structures, such as roots, rhizomes, stolons or creeping stems. The latter contribute to local spread, whereas seeds and detachable vegetative structures can be dispersed, thereby contributing to spread over larger areas.

### **M1a Evidence of reproduction**

*M1a1 Has the plant reproduced in place by joined vegetative structures (e.g. local spread via roots, rhizomes, stolons or creeping stems)?*

Reproduction via detachable vegetative structures is considered to be functionally similar to reproduction via seeds and is covered under the next question.

Yes = 1

No = 0

*M1a2 Has the plant reproduced by seeds or detachable vegetative structures (e.g. stem segments, bulbils, and aerial tubers)?*

Yes = 2

No = 0

## M1b Pre-reproductive (juvenile) period

*How long does it take for a new individual to produce seeds or other propagules?*

The answer to this question will give some idea of the potential rate of spread of the species. Plants with shorter life cycles will, in most cases, spread faster than those with longer life cycles, thus increasing the likelihood component of weed risk. Time to reproduction will be closely related to growth form, with annual species reproducing in less than 1 year, most herbaceous perennials reproducing in 2 years or less, and most woody species requiring more than 2 years to mature. Here the distinction between species with short and long juvenile periods is similar to that used by Panetta (2015) for the determination of eradication feasibility. Additional information relating to time to reproduction for individual species may be found through internet searches (see list of databases and websites in Appendix 4).

Less than 1 yr = 3

1 to 2 yrs = 2

More than 2 yrs = 1

Default for shrubs and trees = 1

## M1c Evidence of spread

*M1c1 For connected vegetative spread:*

Spread to less than 1 m = 0

Spread more than 1 m = 1

*M1c2 For spread via seed or detachable vegetative propagules:*

Where seedlings and other young plants are present and can be linked with presumed parent plants, it is important to gain some idea of how far from parent plants that seedlings have established. Seedling numbers and density generally decrease rapidly with increasing distance. It is not the aim of this question to determine the furthest extent of seedling establishment—this would be an objective of delimitation. Rather, the aim is to determine whether seedling recruitment has occurred at a substantial distance during the time for which the plant has been present.

To answer this question, walk for approximately 100 m in different directions away from the presumed parent, noting when the last seedling or young plant is detected. *For the direction in which plants are detected at the greatest distance, score as follows, where final detection occurs at:*

Less than 10 m = 1

10 to 50 m = 2

More than 50 m = 3

For guidance, maximum potential invasiveness scores for plant growth forms are shown below.

**Table 7. Maximum invasiveness scores for different terrestrial plant growth forms.**

Question	Growth form					
	Annual	Biennial	Herbaceous perennial*	Shrub	Tree	Climber
M1a	2	2	3	3	2	3
M1b	3	2	2	2	1	2
M1c (veg. spread)	na	na	1	1	1	1
M1c (other spread)	3	3	3	3	3	3
<b>Total</b>	<b>8</b>	<b>7</b>	<b>9</b>	<b>9</b>	<b>7</b>	<b>9</b>

\*Includes aquatic plants; na = not applicable

## **M2 Impact**

The highest risk plant invaders (sometimes referred to as 'ecosystem transformers'; Richardson *et al.* 2000) are those that change the character, condition, form or nature of ecosystems, particularly over large areas. This commonly happens when a new layer of vegetation is created by the introduction of a different growth form (e.g. the establishment and proliferation of shrubs in grasslands or wetlands, climbers that scramble over other plants, floating or submerged aquatic plants that can form monocultures).

The impact on biodiversity values is a function of plant cover and total biomass. Because total biomass can be difficult to measure, the cover of a plant is commonly used because it is closely associated with impact. **Here, the assessment of cover is intended to capture plants that "sound an alarm bell" for the observer, indicating that a plant is on the way to becoming dominant, at least locally.**

### **M2a Could species potentially alter community structure?**

This question needs to be interpreted in terms of the growth form of the species and the vegetation structure of the community concerned. Common transformations of community structure are conversion of grasslands or grassy woodlands to communities that have a dominant (invasive) shrub stratum, degradation of forests by climbing plants that overtop trees, and domination of the ground layer by creepers (e.g. *Tradescantia*) that develop monocultures that suppress regeneration of other plants. Aquatic plant invaders may form a floating monoculture (e.g. Water Hyacinth) or dominate as submerged plants (e.g. *Cabomba*).

To answer this question, consider all of the community types that exist in the land unit that is being managed—where the plant occurs now may not be where it could have the greatest effect should it spread. Assistance in answering this question may be found through internet searches based upon the species name as well as through examination of a range of websites and databases (see list of databases and websites in Appendix 4).

Score the answer to this question as 'yes' or 'no', where:

Yes = 5

No = 0

### **M2b Has the plant attained a high level of cover?**

Compared to the situation with animals, for which sizes change very little as density increases, individuals of a plant species may exhibit a wide range of sizes. Owing to competition between individuals of the same species, the sizes of plants may become smaller (or skewed overall, with a few large individuals and many smaller ones) as density increases. Cover is therefore considered to be a better measure of abundance than density. Density is calculated in terms of the number of individuals per unit area, but cover is defined as the proportion of ground occupied by perpendicular projection onto it by the aerial parts of plants. It is usually considered in the horizontal dimension, but for climbers the vertical dimension must be considered as well.

Locate a dense patch of the infestation and record its cover to answer the question below.

This question will be answered as 'yes' or 'no', where 'yes' corresponds to 50% cover over a 2 X 2 m area for species reproducing vegetatively (via structures connected to parent plants), and over a 5 X 5 m area for those reproducing by seed or other propagules. If the plant reproduces by both methods, record the cover that has been achieved through vegetative spread.

Yes = 10

No = 0

If the recommended sample areas (2 X 2 m = 4 m<sup>2</sup> or 5 X 5 m = 25 m<sup>2</sup>) are not available, slightly (e.g. 10-20%) smaller areas can be used; otherwise it will be necessary to monitor the infestation for future increases in cover. If practicable, monitoring at yearly intervals is recommended. The maximum score for impact (i.e. M2a + M2b = 15) is greater than the corresponding score for invasiveness (i.e. M1a + M1b + M1c = 10; Table 7), giving greater weight to the former criterion, which is consistent with the Victorian WRA procedure.

## **Filters**

### **F1 Time-related filtering**

The Local Performance assessment represents a snapshot, taken in the context of processes (i.e. invasion and generation of impact) that may or may not be in train. The amount of information conveyed in this snapshot, as well as the degree of uncertainty associated with the assessment, depend upon how long the plant in question has been present. Residence time is used, together with the juvenile period of the species (i.e. how long it takes a plant to produce seed or other propagules for the first time), to form a judgment on whether a species has had sufficient time to begin to express weed potential. If a plant has been known to be present for a long time, yet has neither increased in abundance nor spread, this also has relevance to the assessment of its weed risk.

#### **F1a Residence time**

*How long has it been since first detection of the plant?*

In many cases, land managers may have detected a species recently, prior to having it formally identified. In other cases, a plant may have been known to occur locally for some time but has become concerning because its population dynamics appear to have changed—it has begun to increase in numbers and spread after a period of no apparent change. The aim of this question is to capture whatever information is available about the period for which the species has been present.

Score according to the number listed below (1–4):

1. Less than 1 yr
2. 1 to 2 yrs
3. Between 2 and 5 yrs
4. More than 5 yrs

Default values = 1–2 years for biennial or perennial herbaceous species (includes aquatic plants) and 2–5 years for woody plants, based on the assumption that plants will have required sufficient time to become reproductive prior to formal identification.

#### **F1b Pre-reproductive (juvenile) period**

As discussed under M1b above, the time that a plant requires to become reproductive is a critical determinant of both its potential rate of spread and how quickly its impacts can be expected to accumulate. The emphasis here, however, is on whether a species has been present for sufficient time to begin to realise its weed potential. Score according to the number listed below (1–3).

*How long does it take the plant to produce seed or other propagules for the first time?*

1. Less than 1 yr
2. 1 to 2 yrs
3. More than 2 yrs

#### **F1c Comparing values for individual filters**

Answers to the questions posed above are used to determine whether residence time exceeds the pre-reproductive (juvenile) period for the species, i.e. if the plant has been growing for longer than its pre-reproductive period. Low values for both the invasiveness and impact measures will be associated with *high* uncertainty if the plant has not been present for long enough to reproduce and *medium* uncertainty if it has (see Figures 6 and 8). (The level of uncertainty will affect the degree of confidence associated with consequent management decisions.)

*Is the number for F1a (residence time) greater than that for F1b (juvenile period)?*

- Yes (uncertainty = Medium)
- No (uncertainty = High)

## F2 Disturbance filtering

A critical aspect of invasiveness for environmental weeds is the ability to establish in intact vegetation (Virtue *et al.* 2006). Many species should be able to establish and increase in areas that experience a high degree of disturbance, but plants that are able to establish and spread in relatively intact vegetation will pose the greatest threat to biodiversity values. The aim of this filter is to assist in identifying the latter group.

Disturbance is a complex topic, in particular the distinction of 'natural' disturbance regimes from those that are dominated by human activities. Some types of natural disturbance are associated with particular habitats, e.g. flooding along watercourses and in wetland habitats, or with particular types of vegetation, e.g. highly flammable vegetation that is prone to fire. Where fire is concerned, the human 'footprint' may be large, operating via prescribed burning or other intentional (arson) or accidental causes. For the purposes of this screen the nature of the fire regime is not important, only whether the site that the species of concern is invading has been burned recently. Where stands of natural vegetation are located adjacent to a different type of land use (e.g. agricultural land) or are associated with infrastructure such as roads and tracks, the effects of human-induced disturbance are commonly referred to as 'edge effects'.

The distance over which edge effects operate will vary according to vegetation type, but for forests, where light is the most important factor, the incidence of weeds drops noticeably by 10 m away from the edge (Fox *et al.* 1997; Pauchard and Alaback 2006). Because it is not always a simple matter to determine to what distance edge effects persist, especially for communities other than forests, distance from an edge plus the presence of disturbance-adapted introduced species are employed to evaluate the importance of human-related disturbance. Linear reserves, such as those occurring along roadsides, have high edge-to-area ratios. If such reserves are sufficiently narrow they may be subject to edge effects throughout.

F2a Does the plant occur only in areas that have been recently (i.e. within the past few years) subjected to disturbance or are adjacent to an edge between natural vegetation and another land use?

Yes = 1

No = 0

F2b What is the maximum distance that the plant (including seedlings) occurs from an edge?

Only edges between natural vegetation and other land uses (e.g. roads, tracks or agricultural land) are considered. Distance from the edge is measured *into* the natural vegetation, not in the other direction. Note that if reserves are narrow there may be no area that is free from edge effects.

Use the information gathered under question M1c to assist in answering this question.

Less than 10 m = 3

10 to 20 m = 2

More than 20 m = 1

F2c Is the plant associated with other species that are commonly considered indicators of disturbance?

Such species will generally be annuals and other early colonisers. Common colonisers of edges, whether they occur next to agricultural land or roads and tracks, include Yorkshire Fog (*Holcus lanatus*), Perennial Veldtgrass (*Ehrharta calycina*), Large Quaking-grass (*Briza maxima*), Spear Thistle (*Cirsium vulgare*), Smooth Cat's Ear (*Hypochoeris glabra*), Cape Weed (*Arctotheca calendula*), Kikuyu (*Pennisetum clandestinum*) and Flax-leaved Broom (*Genista linifolia*). Indicators of other types of disturbance are too many and varied to be listed here. If in doubt, the answer should be 'no'.

Yes = 1

No = 0

## Assembling the screen

The screen consists of two decision trees that relate to the Local Performance evidence (Figures 5 and 6) and a weed risk matrix that combines scores for both Local Performance and Weed History (Figure 7), along with recommended management activities (Figure 8). The decision tree presented in Figure 5 is based upon the scores for invasiveness and impact, plus a score for the disturbance filter. When scores for either invasiveness or impact are less than critical values (5) and the disturbance score is less than 4, there is insufficient evidence for the realisation of a threat to biodiversity values. This is because the plant occurs only under conditions of disturbance, with no evidence (as yet) for its ability to establish and spread in intact vegetation.

The cut-off value for invasiveness (5) corresponds to situations where a plant may reproduce both vegetatively and through the production of propagules, has a long juvenile phase and seedlings, where present, are less than 10 m from a parent plant. The cut-off for impact (5) corresponds to the situation where a species may have *the potential* to alter community structure owing to its growth form, but there no evidence that it has produced sufficient cover to begin to realise this potential. The cut-off value for the disturbance filter (4) corresponds to the situation where the plant occurs only in areas that are disturbance-affected, perhaps with other disturbance-adapted species, and/or only within 10 m of an edge.

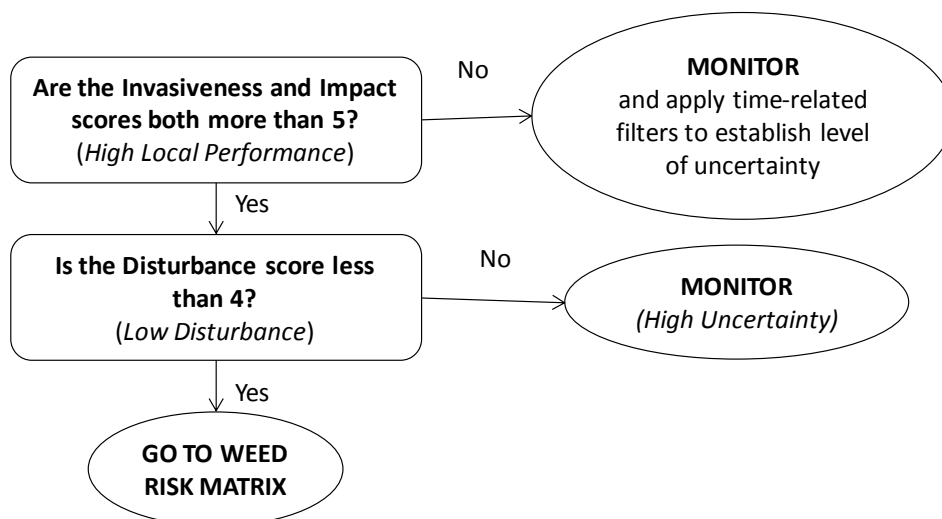


Figure 5. Decision tree for Local Performance evidence, based upon the scores for invasiveness and impact, and the habitat filter (disturbance). High uncertainty associated with the decision to monitor when the Disturbance score is 4 or more exists because there is insufficient evidence to form a judgment on the ability of the plant to invade and cause impact in relatively intact vegetation. If practicable, monitoring at yearly intervals is recommended.

If the scores for invasiveness and impacts are below the cut-off values, this might occur because the species has not been present for sufficient time to demonstrate its potential as a weed. As has been discussed earlier, observations on invasiveness and impact must be interpreted in terms of residence time. In the context of the present screen, if there has been insufficient time for a plant to reproduce there will be no better basis for estimating its local weed risk than the methods that would be employed prior to its introduction (see the Weed History component of the screen). This will be more of an issue for species with relatively long periods between germination and maturity, such as some shrubs and many trees. The time-related filters (residence time and growth form) are combined to provide an estimate of uncertainty associated with the Local Performance evidence (Figure 6).



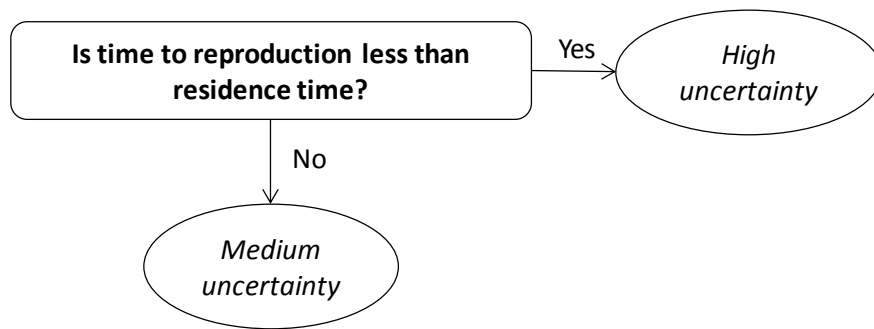


Figure 6. Determination of level of uncertainty associated with Local Performance when the combined scores for invasiveness and impact are below the cut-off value (5). Low values for both the invasiveness and impact measures will be associated with *high* uncertainty if the species has not been present for long enough to reproduce and *medium* uncertainty if it has. Higher uncertainty where residence time is less than time to reproduction reflects a lack of opportunity for the plant to become invasive and cause impact. Different combinations of low and high values for Weed History and Local Performance produce a 2 X 2 weed risk matrix, in which the relative level of each type of evidence varies between cells (Figure 7).

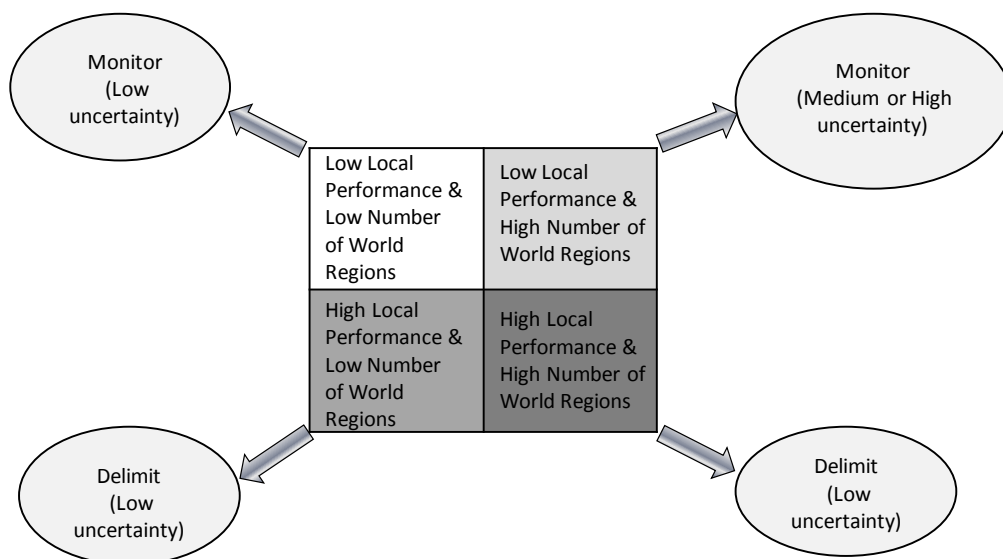
		Number of regions	
		2 or fewer	More than 2
Local performance	Low	Low Local Performance & Low Number of Regions	Low Local Performance & High Number of Regions
	High	High Local Performance & Low Number of Regions	High Local Performance & High Number of Regions

Figure 7. Weed risk matrix representing different levels of evidence for both Local Performance and Weed History (number of regions). The shading intensity for combinations of evidence varies in order from the least (no shading) to the most (heaviest shading) evidence overall.

Many species that will be encountered may have been introduced repeatedly around the world, having had ample opportunity to naturalise, become invasive and to cause negative impacts. However, the possibility remains that a plant that has little previous history of introduction will be encountered. For example, in New Zealand most of the introduced species first collected in the wild prior to 1940 had a history of weediness elsewhere, whereas 20% of the species naturalised towards the end of the last century had no weed history beyond New Zealand (Williams *et al.* 2001).

Because the screen must have the capacity to identify threats to biodiversity from species that have no weed history, Local Performance evidence is given more weight in the determination of management actions. In both cases where Local Performance evidence is strong, the choice of delimitation is associated with a low level of uncertainty (Figure 8). Uncertainty is also low in the case where both Local Performance and Weed History evidence is weak, in which case the recommended action is to monitor so that there will be grounds to reassess the species in the event that local performance changes. Where Local Performance evidence is weak and Weed History evidence is strong, the recommended action is to monitor, associated with either medium or high uncertainty, depending on whether or not residence time exceeds time to reproduction for the plant in question (Figure 6). Many so-called 'sleeper weeds' (Grice and Ainsworth

2002) would fit into this category. Management actions associated with this category will be considered further below.



**Figure 8. Management actions and associated levels of uncertainty for different combinations of Local Performance and Weed History evidence. When uncertainty is low, the land manager can have more confidence that the management decision is a correct one than if the level of uncertainty is medium (or high).**

### Decisions related to single versus multiple assets

The purpose of the screen described above has been to assist in the selection of candidates for delimitation within a single protected area. In this situation, the number of species for which delimitation is attempted will depend upon the local budget for weed management. However, if the objective is to optimise the allocation of delimitation efforts across all protected areas in Victoria, it will become necessary to compare the respective biodiversity values of each. In the first instance the system of Ecological Vegetation Classes (Anon. 2014) could be employed for this purpose, but it is likely that the assessment of biodiversity values would need to be made at a smaller scale. This topic is considered to be beyond the scope of the current exercise.

## Concluding remarks

Choosing which species to delimit is basically a matter of 'picking winners'. The cost of getting it wrong is described by economists as an 'opportunity cost', referring to the fact that, given a decision is made to delimit the species, resources allocated to its delimitation might have been better invested in the delimitation of another species if the plant does not in fact pose a high risk to biodiversity values. The Weed History component of the present screen would appear to be a reasonable hedge against making such an error. However, the particular combination of high levels of weed history evidence with low levels of local performance evidence remains problematic. According to the current weed risk matrix (Figure 8), the recommendation for this category (which could include so-called 'sleeper weeds') is for further monitoring rather than delimitation. Additional investigation (e.g. through exploring sources on the internet) on a species-by-species basis may support a decision to delimit some species in this category, employing a precautionary approach.

The practice of targeting sleeper weeds is based upon a belief that even though such plants may not be demonstrating signs of weediness locally, they are worthy of an eradication attempt before they begin to spread, or at least have spread noticeably. Harris and Timmins (2009) have provided a provocative bio-economic argument that, as long as plant invasions are small enough to be feasible as targets for eradication, it is worth attempting to eradicate all or most newly detected ones, even though only a small proportion would be likely to generate serious impacts. However, the hard reality is that the resources available for delimitation, feasibility evaluation and further action will likely restrict the number of candidates that can be tackled in practice.

Calibration has been undertaken for the screen's Weed History component but its Local Performance component cannot be tested until it has been applied in a range of locations. This component will most likely be capable of refinement and improvement with use. Of most immediate concern are the cut-off cover values for impact (i.e. 50% cover over a 2 X 2 m area for plants reproducing vegetatively and over a 5 X 5 m area for those reproducing by seed). These are 'best-guess' estimates, but application of the screen should soon indicate whether they are reliable and robust. In addition, for species with longer juvenile periods (e.g. some shrubs and most trees) there may be situations where seedling density measures are more effective in capturing impact potential. In any case, refinement will occur most quickly if the screen is employed by experienced land managers who objectively and consistently apply the screening criteria.

## Acknowledgements

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## References

- Adair, R., Cheal, D. and White, M. (2008a) Advisory list of environmental weeds of aquatic habitats of Victoria. Department of Sustainability and Environment, Melbourne. ISBN 978-0-0751362-7-0.
- Adair, R., Cheal, D. and White, M. (2008b) Advisory list of environmental weeds of coastal plains and heathy forests bioregions of Victoria. Department of Sustainability and Environment, Melbourne. ISBN 978-0-0751362-7-0.
- Adair, R., Cheal, D. and White, M. (2009a) Advisory list of environmental weeds of the inland plains bioregions of Victoria. Department of Sustainability and Environment, Melbourne. ISBN 978-0-0751362-7-0.
- Adair, R., Cheal, D. and White, M. (2009b) Advisory list of environmental weeds of the mallee bioregions of Victoria. Department of Sustainability and Environment, Melbourne. ISBN 978-0-0751362-7-0.
- Adair, R., Cheal, D. and White, M. (2009c) Advisory list of environmental weeds of the ranges bioregions of Victoria. Department of Sustainability and Environment, Melbourne. ISBN 978-0-0751362-7-0.
- Adair, R.J. and Groves, R.H. (1998) Impact of environmental weeds on biodiversity: a review and development of methodology. Environment Australia, Canberra.
- Andersen, M.C., Adams, H., Hope, B. and Powell, M. (2004) Risk assessment for invasive species. *Risk Analysis* 24, 787–793.
- Anon. (2014) Ecological Vegetation Class (EVC) Descriptions, Victorian Department of Environment and Primary Industries. URL: [http://vro.depi.vic.gov.au/dpi/vro/wgregn.nsf/pages/wg\\_vegetation\\_res\\_evc\\_descriptions](http://vro.depi.vic.gov.au/dpi/vro/wgregn.nsf/pages/wg_vegetation_res_evc_descriptions)
- Blood, K., James, R. and Panetta, F.D. (2016) Managing weeds: assess the risk guide. A guide for assessing the risk for weeds at the early stage of invasion on public land in Victoria. Department of Environment, Land, Water and Planning, Victoria. ISBN 978-1-76047-004-3 (Print); ISBN 978-1-76047-005-0 (pdf/online).
- Byers, J.E., Reichard, S., Randall, J.M., Parker, I.M., Smith, C.S., Lonsdale, W.M., Atkinson, I.A.E., Seastedt, T.R., Williamson, M., Chornesky, E. and Hayes, D. (2002) Directing research to reduce the impacts on nonindigenous species. *Conservation Biology* 16, 630-640.
- Daehler, C.C. and Virtue, J.G. (2010) Likelihood and consequences: reframing the Australian weed risk assessment to reflect a standard model of risk, In Daehler, K., Pheloung, P. and Williams, P. (eds) International Weed Risk Assessment workshop proceedings, Perth WA 2007. *Plant Protection Quarterly* 25, 52-55.
- Diez, J.M., Hulme, P.E. and Duncan, R.P. (2012) Using prior information to build probabilistic invasive species risk assessments. *Biological Invasions* 14, 681-691.
- Dodd, A.J., Ainsworth, N., Burgman, M.A., McCarthy, M.A. (2015) Plant extirpation at the site scale: implications for eradication programmes. *Diversity and Distributions*, 21, 151–162.
- Drenovsky, R.E., Grewell, B.J. and D'Antonio, C.M. (2012) A functional trait perspective on plant invasion. *Annals Of Botany* 110, 141–153.
- Fox, B.J., Taylor, J.E., Fox, M.D. and Williams, C. (1997) Vegetation changes across edges of rainforest remnants. *Biological Conservation* 82, 1-13.
- Fried, G. and Panetta, F.D. (in review) Looking for thresholds in impacts of the invasive groundsel tree (*Baccharis halimifolia* L.) in Mediterranean saltmarsh communities Submitted to *Journal of Applied Ecology*.
- Gooden, B., French, K., Turner, P.J. and Downey, P.O. (2009) Impact threshold for an alien plant invader, *Lantana camara* L., on native plant communities. *Biological Conservation* 142, 2631-2641.
- Grice, A.C. and Ainsworth, N. (2002) Sleeper weeds—a useful concept? *Plant Protection Quarterly* 18, 35-39.

- Groves, R.H., Boden, R. and Lonsdale, W.M. (2005) Jumping the Garden Fence: Invasive Garden Plants in Australia and their environmental and agricultural impacts. CSIRO report prepared for WWF-Australia. WWF-Australia, Sydney. URL: <http://www.plantright.org/pdfs/Groves-et-al2005.pdf>
- Harris, S. and Timmins, S.M. (2009) Estimating the benefit of early control of all newly naturalised plants. Science for Conservation 292, Department of Conservation, Wellington, New Zealand.
- Hulme, P.E. (2012) Weed risk assessment: a way forward or a waste of time? *Journal of Applied Ecology* 49, 10-19.
- Humphries, S.E., Groves, R.H. and Mitchell, D.S. (1991) Plant invasions of Australian ecosystems: a status review and management directions. *Kowari* 2, 1-134.
- McAlpine, K.G.L., Lamoureaux, S.L. and Westbrooke, I. (2015) Ecological impacts of ground cover weeds in New Zealand lowland forests. *New Zealand Journal of Ecology* 39, 50-60.
- Myers, J.H., Savoie, A. and van Randen, E. (1998) Eradication and pest management. *Annual Review of Entomology* 43, 471-491.
- Nel, J.L., Richardson, D.M., Rouget, M., Mgidi, T.N., Mdzeke, N., Le Maitre, D.C., van Wilgen, B.W., Schonegevel, L., Henderson, L. and Naser, S. (2004) A proposed classification of invasive alien plant species in South Africa: towards prioritizing species and areas for management action. *South African Journal of Science* 100, 53-64.
- Panetta, F.D. (2009) Weed eradication: An economic perspective. *Invasive Plant Science and Management* 2, 360-368.
- Panetta, F.D. (2015) Weed eradication feasibility: Lessons of the 21st century. *Weed Research* 55, 226-238.
- Pauchard, A. and Alaback, P.B. (2006) Edge type defines alien plant species invasions along *Pinus contorta* burned, highway and clearcut forest edges. *Forest Ecology and Management* 223, 327–335.
- Pheloung, P.C., Williams, P.A. and Halloy, S.R. (1999) A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. *Journal of Environmental Management* 57, 239–251.
- Pyšek, P., Jarošík, V., Hulme, P., Pergl, J., Hejda, M., Schaffner, U. and Vilà, M. (2012) A global assessment of invasive plant impacts on resident species, communities and ecosystems: the interaction of impact measures, invading species' traits and environment. *Global Change Biology* 18, 1725-1737.
- Randall, J.M., Morse, L.E., Benton, N., Hiebert, R., Lu, S. and Killeffer, T. (2008) The invasive species assessment protocol: A tool for creating regional and national lists of invasive nonnative plants that negatively impact biodiversity. *Invasive Plant Science and Management* 1, 36-49.
- Randall, R.P. (2012) *A Global Compendium of Weeds*. Second edition, Department of Agriculture and Food, Western Australia. URL: [http://www.researchgate.net/publication/235869421\\_A\\_Global\\_Compendium\\_of>Weeds\\_Second\\_Edition](http://www.researchgate.net/publication/235869421_A_Global_Compendium_of>Weeds_Second_Edition)
- Richardson, D.M. and van Wilgen, B.W. (2004) Invasive alien plants in South Africa: how well do we understand the ecological impacts? *South African Journal of Science* 100, 45-52.
- Richardson, D.M., Pysek, P., Rejmánek, M., Barbour, M.G., Panetta, F.D. & West, C.J. (2000) Naturalization and invasion of alien plants: concepts and definitions. *Diversity and Distributions* 6, 93-107.
- Roberts, P.D., Diaz-Soltero, H., Hemming, D.J., Parr, M.J., Shaw, R.H., Wakefield, N., Wright, H.J. and Witt, A.B.R. (2015). What is the evidence that invasive species are a significant contributor to the decline or loss of threatened species? CABI, available at URL: <http://www.cabi.org/Uploads/isc/IAS%20Systematic%20Review.pdf>
- Simberloff, D. (2003) Eradication – preventing invasions at the outset. *Weed Science* 51, 247-253.
- van Klinken, R.D., Panetta, F.D., Coutts, S. and Simon, B.K. (2015) Learning from the past to predict the future: an historical analysis of grass invasions in northern Australia. *Biological Invasions* 17, 565-579.

Virtue, J., Cunningham, D., Hanson, C., Hosking, J., Miller, I., Panetta, D., Pheloung, P., Randall, R., Timmins, S., Walton, C., Weiss, J., and Williams, P. (2006) National post-border weed risk management protocol. Standards Australia, Sydney, and Standards New Zealand, Wellington. ISBN 0 7337 7490 3.

Weiss, J.E.R. and Iaconis, L.J. (2002) Pest Plant Invasiveness Assessment. Department of Natural Resources and Environment, Frankston, Victoria.  
[http://vro.depi.vic.gov.au/dpi/vro/vrosite.nsf/0d08cd6930912d1e4a2567d2002579cb/f27bb55e23c41654ca25760800811d46/\\$FILE/PPIA%20report%20.pdf](http://vro.depi.vic.gov.au/dpi/vro/vrosite.nsf/0d08cd6930912d1e4a2567d2002579cb/f27bb55e23c41654ca25760800811d46/$FILE/PPIA%20report%20.pdf)

Williams, P.A., Nicol, E. and Newfield, M. (2001) Assessing the risk to indigenous biota of plant taxa new to New Zealand. In *Weed Risk Assessment* (eds R.H. Groves, F.D. Panetta & J.G. Virtue), pp. 100-116. CSIRO Publishing, Melbourne.

## Further reading

Adair, R., James, R. and Blood, K. (2016) Managing weeds: eradication response guide. A guide for planning and undertaking an eradication response to weeds at the early stage of invasion on public land in Victoria. Department of Environment, Land, Water and Planning, Victoria. ISBN 978-1-76047-010-4 (Print); ISBN 978-1-76047-011-1 (pdf/online).

Blood, K. and James, R. (2016) Looking for weeds: name and notify guide. A guide for identifying weeds at the early stage of invasion on public land in Victoria. Department of Environment, Land, Water and Planning, Victoria. ISBN 978-1-76047-002-9 (Print); ISBN 978-1-76047-003-6 (pdf/online).

Blood, K. and James, R. (2016) Managing weeds: decide the response guide. A guide for determining the appropriate response to weeds at the early stage of invasion on public land in Victoria. Department of Environment, Land, Water and Planning, Victoria. ISBN 978-1-76047-008-1 (Print); ISBN 978-1-76047-009-8 (pdf/online).

James, R. and Blood, K. (2016) Looking for weeds: delimiting survey guide. A guide for planning and undertaking delimiting surveys for weeds at the early stage of invasion on public land in Victoria. Department of Environment, Land, Water and Planning, Victoria. ISBN 978-1-76047-006-7 (Print); ISBN 978-1-76047-007-4 (pdf/online).

Sheehan, M., James, R. and Blood, K. (2016) Looking for weeds: search and detect guide. A guide for searching and detecting weeds at the early stage of invasion on public land in Victoria. Department of Environment, Land, Water and Planning, Victoria. ISBN 978-1-76047-000-5 (Print); ISBN 978-1-76047-001-2 (pdf/online).



## Appendix 1 - User manual extract

The material in this appendix, with the table in Appendix 2, and extracts from the material in the body of this report formed part of the original 'user manual' that were subsequently modified into Blood, James and Panetta (2016).

### Using the screen

For the species of concern, the screen initially requires input of information relevant to both Weed History and Local Performance. Values for the number of world regions in which the species occurs (i.e. Weed History) and summed values for each of the measures (invasiveness and impact) of Local Performance are then used to place the species in a Weed Risk Matrix. From this matrix, suitable management actions are indicated, as well as the level of uncertainty associated with the choice of such actions (see Figure 8).

#### Weed History

For this component of the screen, *A Global Compendium of Weeds* (Randall 2012) is used to determine in how many regions of the world the species of concern has been recorded as an *environmental* weed. (It is assumed that a formal identification of the plant concerned has already been made.)

References in the Compendium are numbered and associated with a letter that indicates the status of the plant (e.g. A = agricultural weed, C = cultivation escape, N = naturalised etc.). References for environmental weeds are designated by an 'E' following the reference number; note 'E' references only. There are 60 pages of references in the compendium, so for ease of use it may be worthwhile printing off these pages (as double-sided copy) if many assessments are to be undertaken.

While searching for information in the Compendium, it is important to note whether synonyms for the species exist (this information is given) and to determine whether additional 'E' references are associated with these names. Any references linked with 'global' locations should be ignored, unless the user has access to the original source and can determine the geographic origin of specific records. Records that correspond to lists of potential weeds should also be discounted, unless, again, primary sources can be accessed to determine whether these lists include any *actual* records of occurrence. Some of these references will have URLs, making such access easy.

Record the number of world regions (see Appendix 2) for example Africa, Australasia (i.e. Australia and New Zealand), Caribbean, Europe, North America, Pacific, South America and Subantarctic.

#### Local Performance

The purpose of this component of the screen is to employ on-ground observations to determine through evidence of early spread and impact whether the candidate species poses a high risk to biodiversity values. In conjunction with information on the candidate's Weed History, assessments of invasiveness and impact from this component will then be used to decide whether to delimit the species or to monitor it, pending further evidence of spread and impact. The values of the measures employed in the assessment of Local Performance are qualified according to how long the species is considered to have been present (i.e. the time-related filters) and whether it occurs only in areas affected by disturbance (i.e. the disturbance filter).

## Appendix 2 - Weed risk screen score sheet and management decision

A modified version of this score sheet template has been incorporated into “Managing weeds: assess the risk guide” (Blood, James and Panetta 2016). Users should use the modified version, not the one below.

Species ..... Screen completed by .....

Species location ..... Date of assessment .....

<b>Weed History</b>	
	Number of world regions
<b>Local Performance</b>	
<b>Measures</b>	<b>Score</b>
<p><b>M1 Invasiveness</b>            Propagules are detachable structures that can grow into new plants. These are commonly seeds, but also include detachable vegetative structures such as stem segments, bulbils, and aerial tubers. Vegetative reproduction can occur via such detachable structures, but more commonly occurs via connected vegetative structures, such as roots, rhizomes, stolons or creeping stems. The latter contribute to local spread, whereas seeds and detachable vegetative structures can be dispersed, thereby contributing to spread over larger areas.</p> <p><b>M1a Evidence of reproduction</b>  <i>M1a1 Has the plant reproduced in place by joined vegetative structures (e.g. local spread via roots, rhizomes, stolons or creeping stems)?</i>            Reproduction via detachable vegetative structures (propagules) is considered to be functionally similar to reproduction via seeds and is covered under the next question.            Yes = 1            No = 0</p>	
<p><i>M1a2 Has the plant reproduced by seeds or detachable vegetative structures (e.g. stem segments, bulbils, and aerial tubers)?</i>            Yes = 2            No = 0</p>	
<p><b>M1b Pre-reproductive period</b>  <i>How long does it take for a new individual to produce seeds or other propagules?</i>            Less than 1 yr = 3            1 to 2 yrs = 2            More than 2 yrs = 1            Default for shrubs and trees = 1</p>	
<p><b>M1c Evidence of spread</b>  <i>M1c1 For vegetative spread via structures connected to parent plants:</i>            Spread to less than 1 m = 0            Spread more than 1 m = 1</p>	
<p><i>M1c2 For spread via seed or independent vegetative propagules:</i>            For the direction in which plants are detected at the greatest distance, score as follows, where final detection occurs at:            Less than 10 m = 1</p>	

10 to 50 m = 2 More than 50 m = 3	
<b>Total score for invasiveness</b>	
<b>M2 Impact</b> <b>M2a Could species <i>potentially</i> alter community structure?</b> Score the answer to this question as 'yes' or 'no', where: Yes = 5 No = 0	
<b>M2b Has the plant attained a high level of cover?</b> Locate a dense patch of the infestation and record its cover to answer the question below. This question will be answered as 'yes' or 'no', where 'yes' corresponds to 50% cover over a 2 X 2 m area for species reproducing vegetatively (via structures connected to parent plants), and over a 5 X 5 m area for those reproducing by seed or other propagules. If the plant reproduces by both methods, record the cover that has been achieved through vegetative spread. Yes = 10 No = 0  If the recommended sample areas (2 X 2 m = 4 m <sup>2</sup> or 5 X 5 m = 25 m <sup>2</sup> ) are not available, slightly (e.g. 10-20%) smaller areas can be used; otherwise it will be necessary to monitor the infestation for future increases in cover.	
<b>Total score for impact</b>	
<b>Filters</b>	
<b>F1 Time-related filtering</b> Only complete this section (i.e. <b>F1a</b> , <b>F1b</b> and <b>F1c</b> ) if the invasiveness OR impact score total is less than 5. The decision made will be to <i>monitor</i> , but this section assists in determining the uncertainty associated with this decision. <b>F1a Residence time</b> <i>How long has it been since first detection of the plant?</i> Score according to the number listed below (1–4): 1. Less than 1 yr 2. 1 to 2 yrs 3. Between 2 and 5 yrs 4. More than 5 yrs  Default values = 1–2 years for biennial or perennial herbaceous species (includes aquatic plants) and 2–5 years for woody plants, based on the assumption that plants will have required sufficient time to become reproductive prior to formal identification.	
<b>F1b Pre-reproductive (juvenile) period</b> <i>How long does it take the plant to produce seed or other propagules for the first time? (see answer to <b>M1b</b>)</i> 1. Less than 1 yr 2. 1 to 2 yrs 3. More than 2 yrs	
<b>F1c Comparing values for individual filters</b> <i>Is the number for <b>F1a</b> (residence time) greater than that for <b>F1b</b> (juvenile period)?</i> Yes (uncertainty = Medium) No (uncertainty = High)  High uncertainty where residence time is less than time to reproduction reflects a lack of opportunity to become invasive and cause impact. Further monitoring will be required to assess weed risk properly for plants that reproduce <i>only</i> via seed or other propagules.	
<b>Time-related uncertainty</b>	

High <input type="checkbox"/> (Further monitoring required)	
Medium <input type="checkbox"/> (Continue assessment)	
<b>F2 Disturbance filtering</b> F2a Does the plant occur <u>only</u> in areas that have been recently (i.e. within the past few years) subjected to disturbance or are adjacent to an edge between natural vegetation and another land use? Yes = 1 No = 0	
F2b What is the maximum distance that the plant (including seedlings) occurs from an edge? Less than 10 m = 3 10 to 20 m = 2 More than 20 m = 1	
F2c Is the plant associated with other species that are commonly considered indicators of disturbance? Such species will generally be annuals and other early colonisers. Common colonisers of edges, whether they occur next to agricultural land or roads and tracks, include Yorkshire Fog ( <i>Holcus lanatus</i> ), Perennial Veldtgrass ( <i>Ehrharta calycina</i> ), Large Quaking-grass ( <i>Briza maxima</i> ), Spear Thistle ( <i>Cirsium vulgare</i> ), Smooth Cat's Ear ( <i>Hypochoeris glabra</i> ), Cape Weed ( <i>Arctotheca calendula</i> ), Kikuyu ( <i>Pennisetum clandestinum</i> ) and Flax-leaved Broom ( <i>Genista linifolia</i> ). Indicators of other types of disturbance are too many and varied to be listed here. If in doubt, answer 'no'. Yes = 1 No = 0	
<b>Total score for disturbance</b>	

<b>Decision making</b>	
<b>Local Performance</b>	<b>Disturbance</b>
Are invasiveness and impact scores both more than 5? Yes <input type="checkbox"/> No <input type="checkbox"/>	Is the disturbance score less than 4? Yes <input type="checkbox"/> No <input type="checkbox"/>
If the answer to the Local Performance question is 'yes' and to the Disturbance question is 'no', <i>delimitation</i> should be undertaken. In most other circumstances the species should be subjected to <i>monitoring</i> over time to detect possible changes in invasiveness and/or impacts. A possible exception to this rule is the situation where the answer to the Local Performance question is 'no', but the species is found in more than two world regions. In this case, additional information relating to potential weed risk gained from online searches may ultimately support a decision to delimit, employing a precautionary approach.	
<b>Decision</b> Delimit <input type="checkbox"/> Monitor <input type="checkbox"/> Where the decision is to <i>delimit</i> , the associated uncertainty is low, meaning that this decision may be taken with confidence. For decisions to <i>monitor</i> , if the answer to the Local Performance question is 'no', the decision is associated with low uncertainty if there is relatively low evidence of Weed History (i.e. the species is an environmental weed in two or fewer world regions). If there is a high level of Weed History evidence, however, the decision is associated with high uncertainty if the time-related filter is failed and medium uncertainty if the disturbance filter is failed. This combination (i.e. high World History and low Local Performance) captures so-called 'sleeper weeds' and is the most problematic. If practicable, monitoring at yearly intervals is recommended to detect changes in invasiveness and/or impact.	

## Appendix 3 - Recommendation on use of a classification presented by Blackburn *et al.* (2014)

This classification represents a standardised method to evaluate and compare the magnitudes of different types of environmental impacts. It categorises impacts by the different mechanisms operating and also presents criteria for assigning alien species to different levels of impact, from minimal to massive. The classification is based upon documented evidence of impact (cf the use of Weed History in the present WRA screen). Its use will clearly be limited by the available evidence for any particular species. In my view the scheme is potentially of most use to DEWLP should a comparison be made of the impacts of different *types* of pest organisms, i.e. plants, animals and micro-organisms.

### Reference

Blackburn, T. M., Essl, F., Evans, T., Hulme, P. E., Jeschke, J. M., Kühn, I., Kumschick, S., Marková, Z., Mrugała, A., Nentwig, W., Pergl, J., Pyšek, P., Rabitsch, W., Ricciardi, A., Richardson, D. M., Sendek, A., Vilà, M., Wilson, J. R. U., Winter, M., Genovesi, P., and Bacher, S. (2014) A unified classification of alien species based on the magnitude of their environmental impacts. *PLoS Biology* 12(5), e1001850. doi:10.1371/journal.pbio.1001850.

## Appendix 4 - Databases and websites

Most of this material is abstracted from the revised National Post-border Weed Risk Management Protocol (in preparation).

Australia's Virtual Herbarium website. This website maps the recorded locations of plant specimens, including exotic species, held within Australia's national and state herbaria.

<http://avh.ala.org.au/>

Atlas of Living Australia. This website contains a collection of data for Natural History Collections for Australia, including plants. The Atlas maps these records and allows access to each data point. Images are available for some species.

<http://www.ala.org.au/>

California Invasive Plant Council website, contains invasive plant inventory, definitions, impacts, completed risk assessments, information, research, distribution/risk maps and useful links.

<http://www.cal-ipc.org/>

Center for Aquatic and Invasive Plants, University of Florida.

<http://plants.ifas.ufl.edu>

eFLORAS.org. Links to online floras from various world regions, including North America and China. Use the Search facility and mark All Floras so that information is obtained from all the floras covered.

<http://www.efloras.org/>

Global Invasive Species Database (GISD). This site focuses on invasive alien species that threaten native biodiversity and covers all taxonomic groups (micro-organisms/animals/plants) in all ecosystems. It includes information supplied or reviewed by expert contributors from around the world on species ecology, distribution, management and impacts, with references and links.

<http://www.issg.org/database/welcome/>

HEAR (Hawaiian Ecosystems At Risk) website. This website has a lot of information on a large range of temperate and tropical weeds for Hawaii as well as for South Pacific islands.

<http://www.hear.org>

INVASIVE SPECIES COMPENDIUM. This website is operated by CABI and contains datasheets, maps, images, abstracts and full text on invasive species of the world.

<http://www.cabi.org/isc/>

PLANTS database, set up by the United States Department of Agriculture. This database covers all species naturalised in the United States of America (USA) and often has links to further information.

<http://plants.usda.gov/topics.html>



PIER (Pacific Island Ecosystems at Risk) website. This website is useful for tropical and sub-tropical species and often gives a great deal of information on species covered. It is regularly updated and frequently contains photographs.

<http://www.hear.org/pier/scinames.htm>

TROPICOS. One of the world's largest databases of plant information, with detailed nomenclature and references, plus herbarium records from the Americas and other parts of the world.

<http://www.tropicos.org>

WEEDS IN AUSTRALIA. This website has a useful list of weeds, including a National Environmental Alert List. It also has a weed identification tool.

<http://www.environment.gov.au/biodiversity/invasive/weeds/>

## Glossary

**Base rate effect (*synonym prevalence*):** How common a phenomenon is within a population. The base rate of high risk weeds is considered to be a small proportion of all the plants that are introduced or that naturalise.

**Biodiversity:** The variety of life in a given area, having a number of components: (1) genetic diversity, or variations in genetic structure among individuals of a species or population; (2) species diversity, or the variety of species (3) higher taxonomic diversity, or the variety of higher taxonomic levels (e.g., families or orders); (4) community diversity, or the variety of identifiable groups of species that occupy and interact in the same habitats; and (5) ecosystem diversity, or the variety of ecological units composed of biological communities interacting with the physical environment (from Randall *et al.* 2008).

**Biodiversity asset:** The area (e.g. nature reserve or park) that is being managed to preserve biodiversity values.

**Biomass:** Biological material derived from living or recently living organisms, in this case plants. Measuring biomass involves harvesting and weighing plant material, usually after it has been dried in an oven. Because this is very labour-intensive undertaking, **cover** is often used as a proxy for biomass.

**Containment:** The aim of preventing or reducing the spread of invasive species, e.g. by preventing invasions into new areas and eradicating any species that are found outside a defined area or beyond a defined line.

**Control:** To implement actions that reduce the effects of a pest organism where it occurs. For weeds, a wide range of methods are used for control, generally falling into the categories of mechanical, chemical and biological control.

**Cover:** The proportion of ground occupied by perpendicular projection onto it by the aerial parts of plants. Because of the layering effect, cover may exceed 100% for a given area, but most measurements of cover do not extend to this level of detail.

**Delimitation/delimit:** The process of determining the full extent of an invasion. This usually involves intensive surveys of areas in which the species is considered likely to be present.

**Early invaders:** These are plants that have **naturalised** and that have started to spread. Since spread has just begun, such plants are not at all widespread and are generally encountered only by chance, unless specifically targeted by search efforts. Co-ordinated management intervention, i.e. eradication or containment, is at its most feasible for plants at this stage of invasion, owing to their highly restricted distributions.

**Ecosystem services:** The important benefits for humans that arise from healthy functioning ecosystems, including production of oxygen, water detoxification, pollination and pest control.

**Ecosystem transformers:** A subset of invasive plants that change the character, condition, form or nature of a natural ecosystem over a substantial area (Richardson *et al.* 2000). These plants, comprising perhaps in the order of 10% of invasive species, have profound effects on biodiversity and should be prioritised for delimitation.

**Eradication:** The elimination of every single individual (including propagules) of a species from a defined area in which recolonisation is unlikely to occur.

**Filters (time-related, disturbance):** Screening mechanisms used to remove from consideration as threats to biodiversity plants that have not been present for sufficient time to demonstrate invasiveness and impact (time-related filters) or that do not invade and/or cause impact in intact vegetation (disturbance filter).

**Invasion:** The process of spread (see **Invasive plants**). The propensity to spread (invasiveness) is one of the two components of weed risk assessment, the other being impact. It is important not to confuse these two components.

**Invasive plants:** Naturalised plants that produce reproductive offspring, often in very large numbers, at considerable distances from parent plants (approximate scales: greater than 100 m; under 50 years for plants spreading by seeds and other propagules; greater than 6 m in 3 years for plants spreading by roots, rhizomes, stolons, or creeping stems), and thus have the potential to spread over a considerable area (Richardson *et al.* 2000).

**Juvenile period (synonym pre-reproductive period):** The time between when a plant appears as a seedling and when it first produces **propagules**.

**Local performance:** On-ground evidence of a plant's invasiveness and impact (as opposed to the *predictions* of invasiveness and impact that are generated through desktop weed risk assessment procedures).

**Management feasibility:** How difficult it will be to attain specific management objectives, such as eradication, containment, or control to a level at which values are not significantly impacted. Feasibility is a function of many factors, e.g. seed persistence, duration of plant **juvenile periods**, and ease of kill. Lower management feasibility is associated with higher management costs and a lower likelihood of achieving the management objective.

**Measures:** Components of **local performance** (e.g. invasiveness and impact) that are quantified through using a scoring procedure.

**Monitor:** To observe and check the **local performance** of a plant species over a period of time, in order to detect increases in invasiveness and impact should these occur. If practicable, monitoring at yearly intervals is recommended.

**Naturalised plants:** Non-indigenous species that sustain self-replacing populations for several life cycles without direct intervention by people, or despite human intervention. Naturalised species are not necessarily invasive, that is they have not (yet) spread any significant distance.

**Pathway:** The combined processes that result in, or drive, the introduction of non-indigenous species from one geographical location to another.

**Propagule:** An independent part of a plant (i.e. a seed or other vegetative structure) that is capable of being dispersed and growing into a new plant.

**Residence time:** The period for which a species has occurred locally. Assessments of invasiveness and impact will be most reliable when the plant has been present for at least a few generations.

**Risk assessment:** The process of identifying, analysing and evaluating the likelihood and consequence of an event taking place. For weed risk assessment, 'likelihood' refers to the probability that an introduced plant will be introduced, establish and spread (i.e. its invasiveness), and 'consequence' encompasses all of the negative impacts that could result as a result of its spread.

**Risk management:** a process of treating identified risks to achieve a balance between realising opportunities for gains while minimising losses. In addition to risk identification and quantification, risk management includes the activities of evaluation, selection and implementation of actions to reduce risk.

**Risk assessment screen:** A method designed to identify species that pose the greatest weed risk, based upon measures of (or characteristics related to) invasiveness (the 'likelihood' component of risk) and impact (the 'consequence' component of risk).

**Sleeper weeds:** Weed populations where there is an identified mechanism preventing rapid population growth or spread. This is problematic, since often the mechanisms are not identifiable until after the weed 'wakens' and, as such, the term is of little practical value.

**Weed:** A plant (regardless of its origin) that has some undesirable impact. This is a purely human (i.e. operational) definition.

**Weed history:** Evidence that a species has been recorded as a weed previously, either in Australia or elsewhere in the world. Weed history is regarded as one of the most reliable predictors of behaviour as a weed when a plant is introduced to a new area or region.

## List of Abbreviations

<i>et al.</i>	et alia (and others)
spp.	species (plural)
URL	Uniform Resource Locator
WAL	Weed Advisory List
WRA	Weed Risk Assessment
WRM	Weed Risk Management
yr	year

**Notes:**

**Notes:**





[www.delwp.vic.gov.au](http://www.delwp.vic.gov.au)