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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

2nd Edition

VICTORIA State Government | Environment, Land, Water and Planning

Photo credit

Cover photo: Parks Victoria and Department staff discuss management priorities at Anglesea, September 2013 (Photo by Kate Blood).

Other publications in this series:

Blood, K., James, R., Panetta, F. D., Sheehan, M., Adair, R., and Gold, B. (2019) Early invader manual: managing early invader environmental weeds in Victoria. Department of Environment, Land, Water and Planning, Victoria. ISBN 978-1-76077-317-5 (Print); ISBN 978-1-76077-318-2 (pdf/online/MS word).

Sheehan, M., James, R. and Blood, K. (2018) Looking for weeds: search and detect guide (2nd Edition). 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 978-1-76077-039-6 (Print); ISBN 978-1-76077-040-2 (pdf/online/MS word).

Blood, K. and James, R. (2018) Looking for weeds: name and notify guide (2nd Edition). 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 978-1-76077-041-9 (Print); ISBN 978-1-76077-042-6 (pdf/online/MS word).

Blood, K., James, R. and Panetta, F. D. (2018) Managing weeds: assess the risk guide (2nd Edition). 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 978-1-76077-043-3 (Print); ISBN 978-1-76077-044-0 (pdf/online/MS word).

James, R. and Blood, K. (2018) Looking for weeds: delimiting survey guide (2nd Edition). 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 978-1-76077-045-7 (Print); ISBN 978-1-76077-046-4 (pdf/online/MS word).

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White, M., Cheal, D., Carr, G. W., Adair, R., Blood, K. and Meagher, D. (2018). Advisory list of environmental weeds in Victoria. Arthur Rylah Institute for Environmental Research Technical Report Series No. 287. Department of Environment, Land, Water and Planning, Heidelberg, Victoria. ISBN 978-1-76077-001-3 (pdf/online).

Panetta, F. D. (2016) Environmental weed risk screen for Victoria: background and development. A report prepared for the Department of Environment, Land, Water and Planning, Vic. ISBN 978-1-76047-017-3 (Print); ISBN 978-1-76047-018-0 (pdf/online).

Victorian environmental weed risk database (2018), search online for 'early invader weeds'.

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About this guide

Should I eradicate this weed, contain it, control it sufficiently to protect the biodiversity values, or monitor it? This guide has been designed to assist you make a decision about what management approach to take with a weed at the early stage of invasion.

Invasive species management is an integral component of any landscape or reserve scale conservation program. This includes weed management.

Increasingly around the world, the benefits of preventing and 'nipping new weeds in the bud' before they become widespread are being appreciated.

About WESI

The Weeds at the Early Stage of Invasion (WESI) Project was created to promote these benefits and enable Department of Environment, Land, Water and Planning (DELWP) and Parks Victoria public land managers adopt this approach.

The WESI project focuses on high risk invasive species at the early stage of invasion that threaten biodiversity. We work with DELWP and Parks Victoria staff looking after public land anywhere in Victoria.

WESI is funded through the Weeds and Pests on Public Land Program. Project information and tools are available at: www.environment.vic.gov.au/invasive-plants-and-animals/early-invaders

Working within a framework

The WESI project has developed a decision making framework that guides public land managers through the process of dealing with invasive plants at the early stage of invasion (see Figure 1). This guide describes in detail a component of the larger framework.

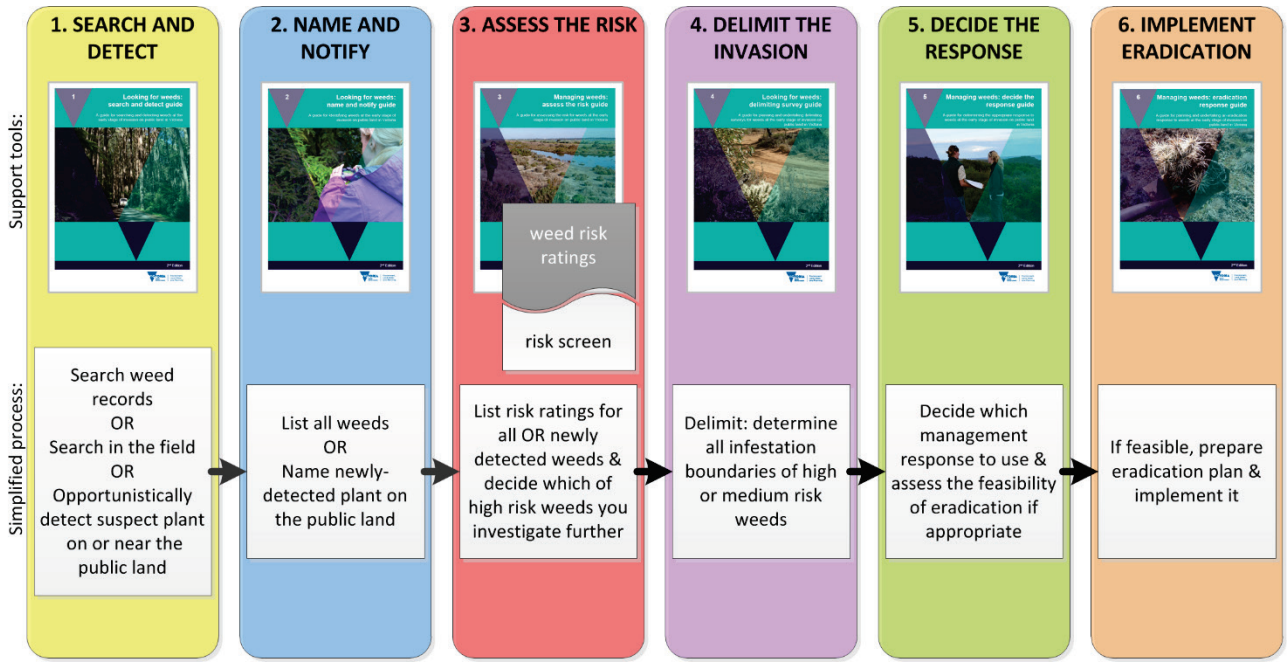


Figure 1 - This is the WESI decision making framework that guides the process for dealing with weeds at the early stage of invasion. There is an enlargement of the framework with scenarios in Appendix 1.

The guide series

Through research and trialling different approaches in the field, there is a growing amount of information about prevention and early intervention for weeds.

This document draws on that research and experience to offer a guide for public land managers, whether they do the work in the field, design the work or authorise the delivery of the work.

By using all the guides in this series, public land managers can improve their decision making about what are the highest risk weeds, how to search for and identify them, determine where the infestation boundaries are, work out which management approach is best and where feasible, respond with local eradication.

The early invader guide series is one of a number of tools available through the WESI project. The series provides step-by-step guides to plan and undertake the following work:

- Search and detect
- Name and notify
- Assess the risk
- Delimit the invasion (comprising all infestations present)
- Decide the response
- Implement eradication (if appropriate)

A summary of the guide series is available with all the blank templates in "Early invader manual: managing early invader environmental weeds in Victoria" (Blood *et al*. 2019). The tools are available at: www.environment.vic.gov.au/invasive-plants-and-animals/early-invaders

Weed management including eradication

Weed activities fall into four broad categories: prevention, eradication, containment and asset-based protection. By better understanding these different management approaches, public land managers can make better decisions, invest resources more wisely, and have better biodiversity outcomes.

Eradication is the elimination of every single individual (including propagules e.g. seeds and buds) of a species from a defined area in which recolonisation is unlikely to occur (Panetta 2016).

There is no denying that eradication is hard to achieve, can take a long time and should only be undertaken for candidates that have a good probability of success. Using these guides will help you make better decisions.

Weed management should not simply be dismissed as 'too hard', but, through some careful planning and a continued and sustained response, can achieve great benefits for biodiversity.

What is 'in the early stage of invasion'?

There is ongoing debate about what area and number of infestations could be classified as eradicable. In reality, the answer depends on the weed and the situation because of the wide variation in the biology and ecology of weeds and the many different environments in which they grow. As a consequence, the relationship between the infestation area and the effort needed to achieve eradication will also vary (Panetta and Timmins 2004).

Through this guide series, we refer to 'weeds at or in the early stage of invasion'. The shortened term is 'early invaders'.

Early invaders are plants that have naturalised and have started to spread. Naturalised plants are non-indigenous species that sustain self-replacing populations for several life cycles without direct intervention by people, or despite human intervention. When 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 (Panetta 2016).

The aim of this guide

The aim of this guide is to assist users with the process of deciding which management approach to take and to determine if eradication is a feasible option. This guide supports the 'Decide the response' step in the framework shown in Figure 1. Use Figure 2 to help you navigate your way around this guide and the others in the series.

Before you start

These guides are full of different 'tools' and hints to help you through the weed management process. You may want to start at the beginning and work your way through step-by-step or browse for ideas in your topic of interest. Managing public land involves balancing many requirements of which weeds are only one. Decisions about which weeds to manage must be made in this broader context.

These guides lead you through the process to eradication of early invaders but generally, eradication will not be the aim for most weeds.

It is essential to be aware of the limitations of these guides, as well as the ongoing need for their modification light of experience, intuition and local knowledge. Effective environmental weed management comes through long-term observations, learned skills and being able to make decisions based on the local conditions. These guides are to help not substitute for these important skills (Blood *et al*. 1996).

How do I decide which response?

I want to decide which approach to take towards a weed at the early stage of invasion in my patch.

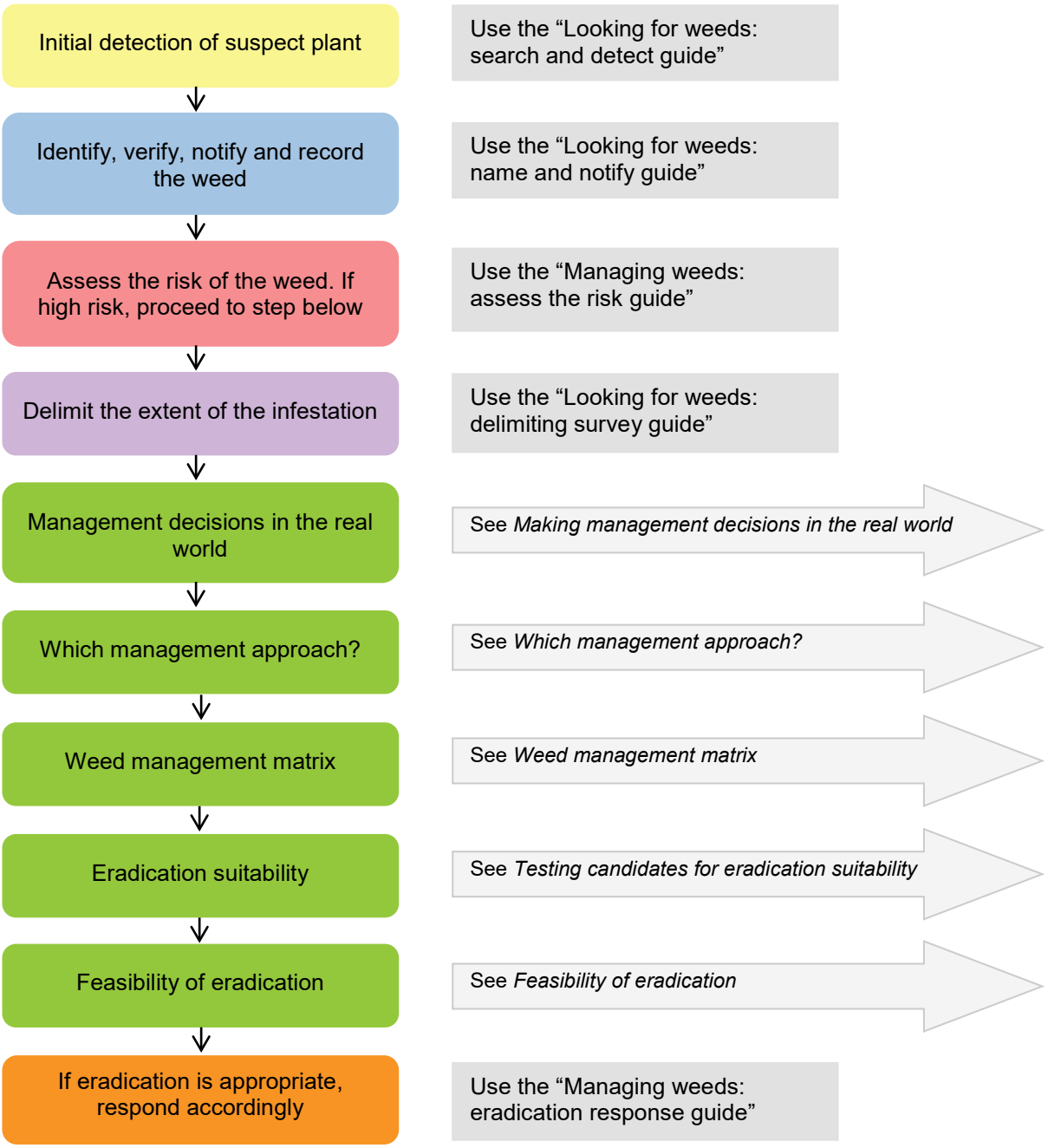
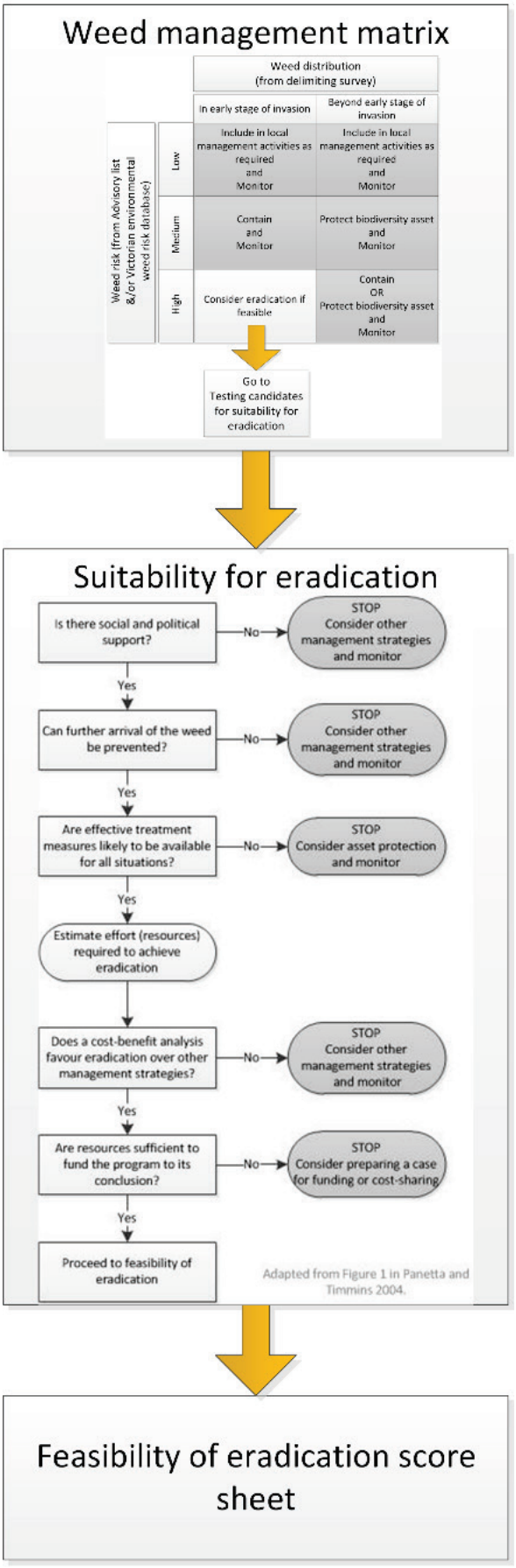


Figure 2 - How to use this guide.



Is eradication feasible?

The aim of this series is to guide public land managers through a decision making framework to identify eradication targets for public land. At each step in the framework, weeds may be identified as unsuitable for local eradication and a different management approach recommended.

Remember, only a small percentage of weeds on public land are suitable for local eradication and we only want to commence an eradication response if it is highly likely that the response will be successful.

If it is unlikely that an eradication response would be successful, then a different management approach should be taken.

This guide will take you through several filters (see Figure 3) to really test if the weed(s) you are considering are realistic local eradication targets:

- Weed management matrix
- Suitability for eradication
- Feasibility of eradication score sheet

Prepare to be challenged to justify carefully every step of the way why a weed should be an eradication target and if not, be prepared to change your management approach.

Weed eradication programs are littered with failures for many reasons. Drawing on that experience, this guide will make it easier to only choose local eradication responses that are likely to succeed.

Note: Some people have found it useful doing the 'Feasibility of eradication' for all the weeds in their patch then the 'Suitability of eradication'. The order may be changed depending on the circumstances and scale of the project.

Figure 3 - Filters used in this guide to determine weeds feasible for local eradication (Figures 5 and 6 have clearer versions of components).

Making management decisions in the real world

It is important to think about the big picture first. This is the time to consider all the fundamental realities of the situation you work in. It calls on being brutally honest with your circumstances.

The reality is that no matter how personally torn you are about protecting an ecosystem or the components within it, in the cold hard light of day if you don't have the resources or political support to act, trying to do so will most likely end in failure, and at its worst, end in compromising your job satisfaction and wellbeing.

By commencing eradication responses that are very unlikely to succeed, the risk is that you'll create a perception that eradication 'never works' and is 'not worth trying'. By picking overambitious targets the effect is to make it less likely that good targets will be funded in the future.

If you are not riding a wave of support and resources to manage what you want now, perhaps the next wave will come in the future. If you have done some of the fundamental planning, you can help prepare yourself or the next land manager to carry on that plan and 'bid' for the required resources and implement your plan when the time is right. Remember that future land manager(s) need to be able to find your plan after you have moved on. The hope is that the weed is not too far gone when resources are available.

Broader management considerations

Before getting into the detail of which species is feasible to eradicate, it's very important to consider some broader management considerations first.

Managing public land involves balancing many requirements, of which weeds are only one. Decisions about which weeds to manage must be made in this broader context.

It may be that your region or area has already made decisions about budgets available for weeds – you will already know what you have to work with. Otherwise, each eradication plan will have to be weighed up against all the other public land management activities. In some circumstances, extra funds will need to be found for an eradication response.

If you do have a weed budget, then there are choices to be made about which weed or combination of weeds to target. You want to spend the limited funds available where you will get the best outcome. Use it also to argue for more resources.

It could be that Statewide environment managers may be receiving additional funding requests from a number of regions/areas. Collaborating with adjoining or other regions/areas dealing with the same weed or circumstance could be beneficial.

The reality is that prioritising amongst multiple eradication targets is very complex and is not simply a matter of using weed risk assessment scores, because factors including estimated cost and duration of eradication come into play.

What do you want to achieve?

Think carefully about the outcome of your management actions. What do you want to achieve? What are you trying to save? Is eradication an achievable aim? Good decision making must consider many things.

It is important to have a very clear understanding of what you want to achieve and it is shared by the people you work with, as well as those with an interest in the area being managed.

Which management approach?

Where is it best to invest limited resources?

If you have been following the decision making framework in its logical progression up to this point, you may have already dropped a number of weeds from consideration for eradication due to their low risk. This is the time when some hard decisions need to be made about which ones to target for eradication.

This is not easy. There are so many variables and every combination of weed and place where it is growing is different. This guide is just that – a guide. You will need to make decisions based on your own circumstances. Get some help. Call in others who are involved in the care and use of the site to help you make the decision.

It is important to capture and record why you have made your decisions if things change in the future and you or others want to revisit these decisions. The completed various early invader templates can be attached to case records created in STAR about each infestation.

Management approach options

Weed activities fall into four broad categories: prevention, eradication, containment and asset-based protection. The diagram below (Figure 4) illustrates how these categories relate to the invasion curve that shows the change in distribution of a weed over time.

Be sure to have a clear understanding of what the different terms mean, as they are often used incorrectly.

In this guide, a number of management approaches are described. Using the weed management matrix (see Figure 5), the appropriate management approach can be determined for each weed and situation being considered.

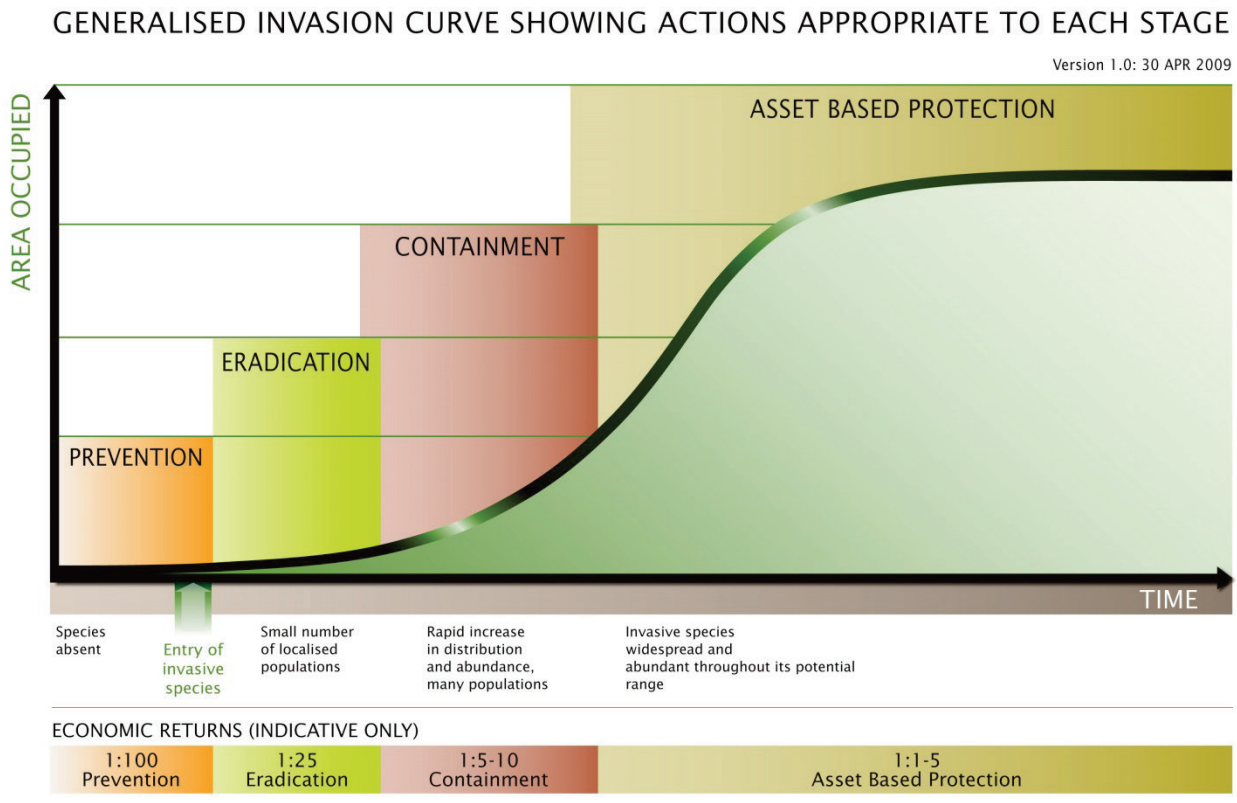


Figure 4 - The invasion curve illustrates the different management approaches and the benefit of investing in different stages of the invasion process (Victorian Government 2010).

In Figure 4, you can see that investing in early intervention through eradication when it is feasible gives a much higher return on investment (1:25 i.e. for every $1 invested in eradication, you get the equivalent of $25 return in benefits) compared to asset protection when a weed is well established over a larger area (1:1-5 i.e. for every $1 invested in asset protection, you only get the equivalent of between only $1 to $5 return in benefits).

The economic returns and benefit to biodiversity are much greater when weeds are prevented or are removed when only in small numbers.

When managing large landscapes, finding the right balance between where to invest in different parts along the invasion curve is challenging. The general argument is to “protect the best first”. Is it better to invest more in feasible eradication or asset protection? The balance will depend on the circumstances.

Prevention

It can be assumed that because a weed is being considered for eradication, it is present so beyond the prevention approach. However, observations about the weeds that are present and knowledge of the land use and plants growing around public land can help to focus effort for appropriate prevention activities for the future. Prevention also includes following hygiene protocols for vehicles, equipment, people and materials etc. being brought into the public land. Investing in good hygiene practices is the most effective way of preventing the arrival and establishment of new weeds, pathogens etc.

Protect biodiversity asset (asset protection, asset-based approach)

A biodiversity asset is the area (e.g. nature reserve or park) that is being managed to preserve biodiversity values.

In this approach multiple weed management activities are prioritised based on the relative value of the biodiversity assets that will be protected by the management activities. The aim is to maintain the viability of the important biodiversity assets and maximise biodiversity outcomes.

The Victorian Government’s NaturePrint is a mechanism to integrate and analyse available information on a range of biodiversity values, threatening processes and ecosystem function at the landscape scale. It is biodiversity information presented spatially.

Seek advice from your biodiversity managers on the best current way to identify the high priority biodiversity assets for your public land.

Other ways of determining priority biodiversity assets can be found in the “Guidelines and procedures for managing the environmental impacts of weeds on public land in Victoria 2007” (Environmental Weeds Working Group 2007) and in Downey *et al.* 2010.

Containment

Containment is the prevention or reduction of 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 (Panetta 2016).

Containment is commonly advocated as fall-back to eradication, but it is not necessarily easier than eradication. If you can’t eradicate, chances are that you cannot contain either, at least in an absolute sense, which means total prevention of further spread. However, as indicated above, slowing spread is also a form of containment and may be a justifiable management objective (Panetta and Cacho 2012). In either case it should be noted that when containment is the aim, there is no end point to management.

Containment feasibility can be considered using short-distance or long-distance dispersal, with or without the involvement of human-mediated dispersal (e.g. directly by humans, on clothes, by human transport, equipment, pets and livestock (Wichmann *et al*. 2009; Panetta 2015).

Eradication

Eradication is the elimination of every single individual (including propagules) of a species from a defined area in which recolonisation is unlikely to occur (Panetta 2016).

The longevity of viable seeds (or other propagules) will indicate the length of the eradication response. The weed's seedbank and budbank must be completely exhausted to ensure no new plants will grow and reproduce. If the weed does regrow and reproduce, the 'response clock' must go back to zero and counting started again, delaying success or tipping a response beyond feasible.

The common reasons local eradication responses are not successful is because land managers fail to:

- correctly delimit the boundaries of the infestation i.e. fail to determine its full extent;
- visit the infestation frequently enough to monitor for regrowth;
- consistently treat the weed, allowing plants to grow to sufficient maturity to reseed;
- prevent reinvasion of the weed being eradicated locally; and
- account for the seedbank and budbank longevity in the soil and stop monitoring too soon.

Useful references on eradication include Panetta (2007) and Panetta (2015).

Monitoring

Monitoring is an important component of all these management approaches. For the purposes of these guides, to monitor is 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. Generally, monitoring at yearly intervals is recommended (Panetta 2016).

There are other forms of monitoring, depending on the purpose. Of most relevance to this guide series, apart from weed monitoring, is monitoring biodiversity for changes associated with invasive plants (see Ainsworth *et al.* 2008). Monitoring results should be recorded in the Spatial, Temporal, Activity Recorder (STAR).

Parks Victoria have a draft monitoring guide available from the agency's research team.

The NSW Bitou Bush monitoring manual (Hughes *et al.* 2009) provides some useful information and templates.

Communication and engagement

Communication and engagement are very important components of all management approaches.

Effectively engaging with staff, volunteers and other stakeholders is essential for the success of weed management. Agencies have communication officers who can assist with the planning and carrying out of engagement. DELWP has a series of useful engagement guides (Riches 2005: book 1, 2, 3), and Kruger *et al.* (2010) is also useful.

Weed management matrix

The matrix below brings together the information you have collected so far on weed risk and distribution information from delimiting surveys.

Determine where the weed(s) you are considering fall within the matrix (Figure 5). This is a way of helping to work out which management approach to take. Remember it is not an exact science, it is a guide. The weed management matrix below should not be confused with the weed risk matrix described in the “Managing weeds: assess the risk guide”.

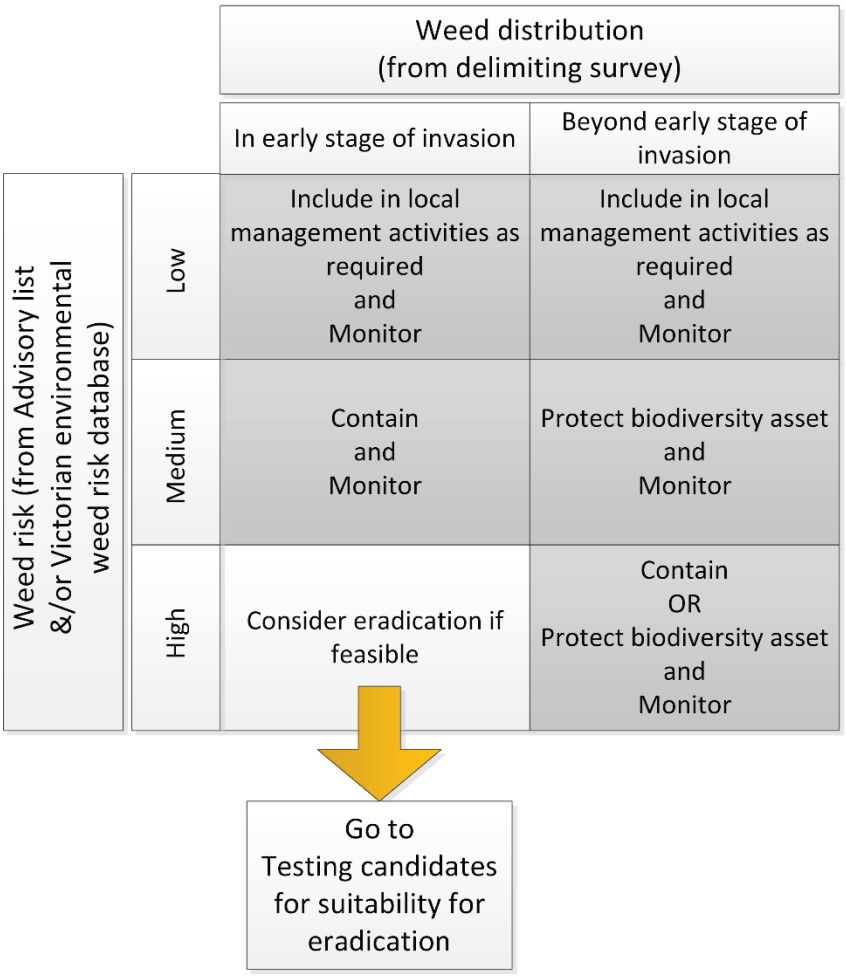


Figure 5 - Weed management matrix.

If the weed(s) you are considering are high risk and in the early stages of invasion, move on to the next section of the guide, suitability for eradication. The next part of the process will help you further test if they are candidates for eradication.

If the weed(s) you are considering are either not high risk and in the early stages of invasion, or are not high risk and beyond the early stages of invasion, then consider the other appropriate management approaches recommended in the weed management matrix. Further reading on these other approaches is available in the bibliography.

Always record your management decisions in the Spatial, Temporal, Activity Recorder (STAR).

Testing candidates for eradication suitability

The process below guides you through a series of questions to test if the weed(s) are suitable candidates for eradication. If they make it through this process, they will be tested for feasibility of eradication in the next section.

The process below (Figure 6) has been adapted from Panetta and Timmins (2004), which is a great reference if you want to learn more about the details of testing eradication candidates.

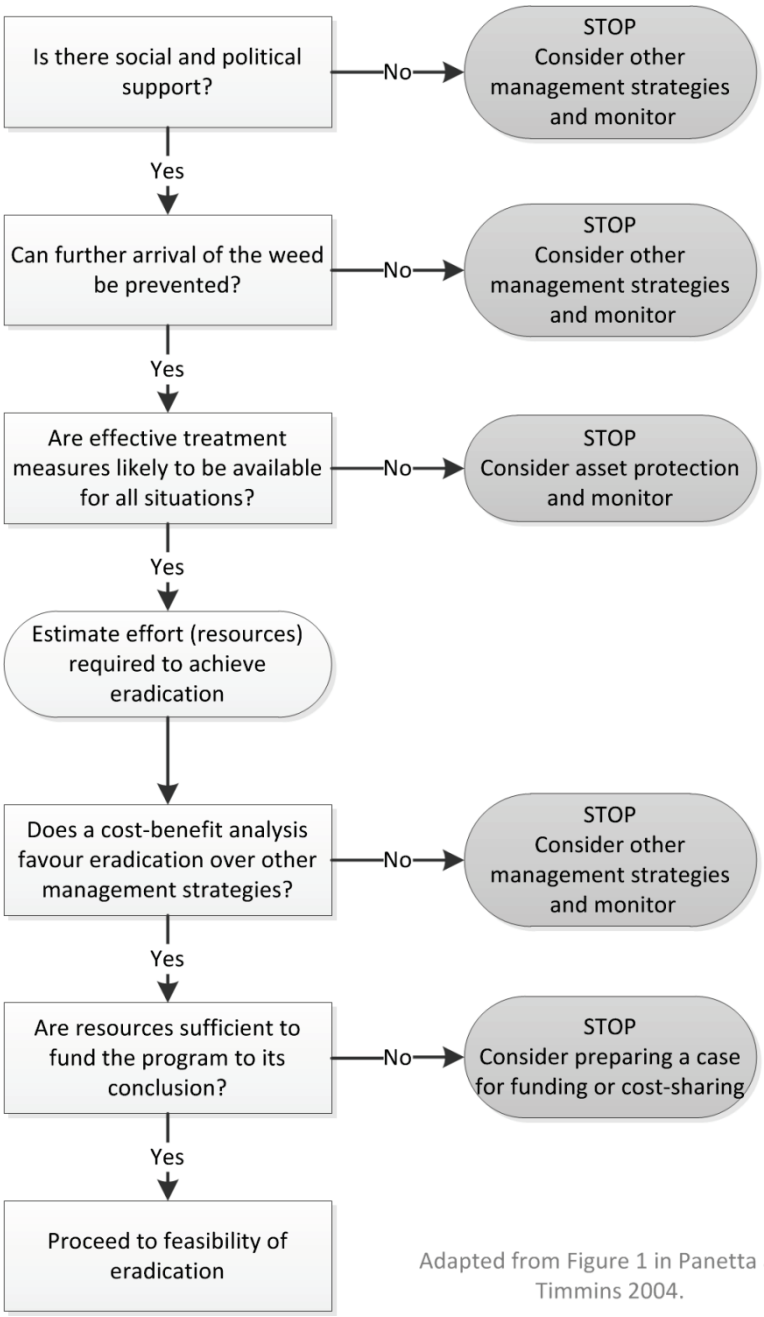


Figure 6 - Suitability for eradication to test and narrow numbers of eradication candidates (based on Panetta and Timmins 2004).

This document is very focussed on the initial decision concerning whether to attempt eradication. This decision is based on the information available at the time; as an eradication response proceeds it is frequently found that new information emerges e.g. additional sites are found, treatments work better or worse than expected etc. A decision to run an eradication response is subject to review and it is normal that some attempts will be halted after a short time – be prepared for this possibility.

Is there community and agency support?

If the socio-political environment is not suitable, the weed(s) are unlikely to be successful eradication targets. Social considerations include conflicts of interest surrounding the plant e.g. is it used for timber or honey production, or is it a popular garden plant? Is it used for habitat by indigenous wildlife? Gauge if there is likely to be social resistance.

Can you gather agency support? What information do you need to build a case to obtain support? Do you need more risk information such as a full Weed Risk Assessment? Do you need to calculate the probability of success?

If there are multiple land management agencies involved over different land tenures, it is less likely that eradication will be achieved. If one agency is unable or unwilling to participate, eradication is likely to fail.

If there is not sufficient socio-political support, then STOP. Consider preparing a case for support if appropriate; otherwise consider a different management approach.

Can further arrival of the weed be prevented?

If you know how the weed arrived, can you prevent this from happening again in the future? If you can only assume how the weed arrived, do you have any influence over those likely pathways into the public land, or over the sources from where they are likely to have come from?

Weeds in cultivation and/or trade

In some of the scientific literature about eradication, the argument is that if a weed has been or is still in cultivation and/or widely in trade i.e. sold in nurseries, garden centres, at markets, traded between gardeners etc., then eradication is not appropriate as a management approach (Panetta and Timmins, 2004).

This may be the case at the national, statewide or regional level, but at the local level, local eradication (also known as extirpation) can still be an appropriate goal if the target plant has been in trade. What is important is if the weed is on the boundary of the public land or within a buffer around the public land where there is a pathway that could bring it in.

If you are unlikely to remove the local source or prevent the weed from arriving again, then STOP and consider a different management approach and monitor.

Are effective treatment measures likely to be available for all situations?

Are effective treatment techniques available for all the different circumstances the weed is growing in in the management area? If techniques are not well developed or off-label herbicide advice is required, delays or failures from poor trialling of previously untested techniques can result in eradication failure.

If effective treatment methods are not available, then STOP and consider asset protection and monitor.

Estimate effort (resources) required to achieve eradication

Do you know how much it will cost and the estimated resources required to have a continued and sustained response until the weed is locally eradicated? This includes having in place long-term funding beyond the typical three year funding cycle, as well as suitably skilled staff.

Draw on the results of the delimiting survey to calculate the area requiring treatment. After delimitation has been achieved, the effort (and hence investment) to achieve weed eradication

comprises the search and control effort required to prevent reproduction until eradication occurs over the infested area. Multiple visits to infested sites need to be factored in for weeds that are difficult to detect, reproduce quickly and produce long-lived propagules. It is probably better to overestimate the effort required, as the costs involved in eradication are generally underestimated (Simberloff 2003). Models are available to estimate eradication duration and costs (Panetta 2015).

Some agencies/managers determine a threshold under which authorisation is not required to carry out treatment of early invaders e.g. $1,000 locally. Over this threshold and further investigation and agency consultation is required (pers. comm. Stephen Platt 13/1/2011).

Panetta and Timmins (2004) and Panetta (2015) go into this topic in more depth.

The human 'resource' element in eradication success

Successful eradication requires a continued and sustained response. Infested areas must be thoroughly searched on a regular basis for new seedlings and treated accordingly. This needs to continue until the viable seed and budbank has been exhausted. Do you have the right people to carry that through?

Look for characteristics and circumstances of individual staff involved to gauge likely barriers to carrying out this eradication work successfully.

Are staff authorised by their supervisors and managers to do the work and is such work written in their position description and performance plan?

Is the workload realistic? Are staff expected to be away in the field for extended periods away from their homes and families and other commitments?

Do staff need mentoring, on the job training or more formal training to make sure they have the skills and knowledge required? Do they need guidance on where to find additional information? What will give them the confidence to carry out the work successfully? Do they understand the fundamental principles of eradication?

Unplanned calls away from the work to undertake other duties such as emergency response, or unplanned leave from work can create a sufficient gap in a response program for a weed to grow and reproduce. Are additional staff or contractors required to fill a short or long-term gap to maintain the response program?

Can you influence staff to increase their ownership of target sites?

Does a cost-benefit analysis favour eradication over other management strategies?

Preparing a cost-benefit analysis should further highlight if eradication is the appropriate response. It could also indicate a tipping point over which eradication is no longer the appropriate approach once a local eradication response has commenced. Once past the tipping point, it is time to consider a different approach. Note that such an analysis need only be a rough one, given the generally good returns on such an investment (Figure 4). In practice, the availability of the amount of resources required to complete an eradication program is likely to be the more critical aspect (see below).

If not, then STOP and consider other management strategies.

Are resources sufficient to fund the program to its conclusion?

If sufficient funding is not available, what information do you need to build a case to obtain funding? Do you need more evidence? Do you need to calculate the probability of success?

If not, then STOP and consider preparing a case for funding or cost-sharing, or consider a different management approach.

If you have made it through this suitability test, with the characteristics that suggest eradication is a suitable response, then proceed to the feasibility of eradication section.

Feasibility of eradication

If you have got this far with weed(s) that appear to be suitable candidates for eradication, they are now about to be tested for their feasibility of eradication.

Assessing the feasibility of eradication

A score sheet has been developed to assess the feasibility of eradication (Appendix 2).

Using this score sheet requires access to information about the weed's biology, the formation of the infestation that is being considered and the location in which it occurs. Some information sources are provided in Appendix 3. Field work will be required and hygiene, wellbeing and safety are important considerations for field activities (see Appendix 4).

Keep in mind that while the answers to the questions in the score sheet can help you test if eradication is feasible, your decisions will still depend on the real world situation that you operate in and will rely on the support of the agency manager.

The completed score sheet below (Table 1) shows a score that will indicate the effort required to eradicate a weed from a particular place. The score can be compared to other weeds at the same location to see if one is more feasible to eradicate than another. The example in Table 1 is to illustrate its use and a blank template is provided in Appendix 2.

Terminology

There are a couple of concepts to clarify before using the score sheet below.

Gross and net infestations: Net infested area is the area requiring treatment (Panetta and Timmins 2004; Dodd *et al.* 2015), while gross infestation area includes the net areas that require treatment plus the surrounding area that must be searched in return trips following treatments (Panetta and Timmins 2004). See Figure 7 for an illustration of these terms.

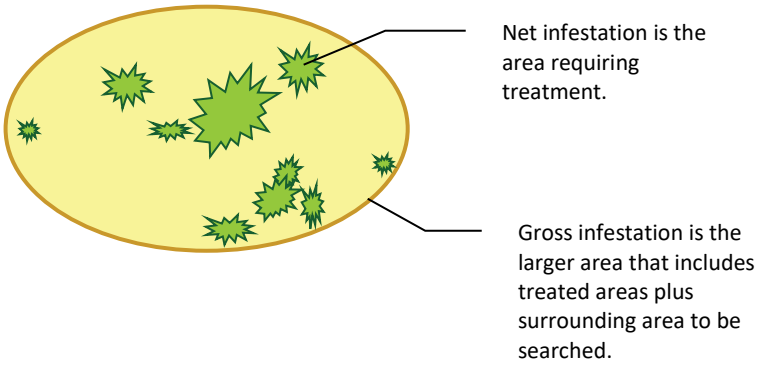


Figure 7 - Illustration explaining the difference between net and gross infestations.

Vegetative structures, joined or detachable: 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 or joined 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 (Panetta 2016).

Feasibility of eradication score sheet

How to use the feasibility of eradication score sheet (Appendix 2) for weeds at the early stage of invasion:

1. Record the appropriate score for each question then sum the scores at the bottom of the table.

2. The score produced by using the table gives an indication of the comparative eradication effort i.e. the effort required to eradicate a weed from a particular place. Estimates of eradication effort are by nature crude, but can be useful guides, especially when trying to determine if one weed is more feasible to eradicate than another. There is no cut-off or threshold score – you do as much as you can with the funding available.

3. Attach a copy of the completed score sheet to the appropriate record in the Spatial, Temporal, Activity Recorder (STAR).

How to find information about the target species

An assessment of eradication feasibility will require knowledge of critical aspects of a target plant's biology and ecology e.g. how long it takes for a newly emerged plant to become reproductive, how its seeds are dispersed and for how long seeds may remain viable in the soil seed bank. Seed persistence will ultimately determine the length of an eradication program and is therefore a critical feature, but there may be nothing known about this for the species of concern; in this case use the default value indicated in the score sheet. A number of useful sources of information are presented in Appendix 3.

Feasibility of eradication case study - White-spined Hudson Pear (*Cylindropuntia pallida*) at Ouyen State Forest

The feasibility of eradication score sheet (Appendix 2) was used for *C. pallida* at Ouyen State Forest (Table 1). Measurements and observations were collected in the field and then the score sheet completed in the office. A blank template is provided in Appendix 2.

Table 1 - Example of a completed feasibility of eradication score sheet for White-spined Hudson Pear (*Cylindropuntia pallida*) at Ouyen State Forest (score sheet based on the work of Panetta and Timmins (2004) and Dodd *et al.* (2015), with modifications according to Aaron Dodd, Kate Blood and Bec James).

Species:	**White-spined Hudson Pear (*Cylindropuntia pallida*)**	**Name of assessor:**	**Bec James**
Location of weed:	**Ouyen State Forest**	**Date of feasibility assessment:**	**3.9.2012**

Factor	**Feasibility of eradication question**	**Scores options for gross infestations e.g. "can we eradicate weed from the park?"**	**Score**
Area	What is the gross area of the weed infestation being assessed?	Less than 1 ha = score 0	**6**
		2 to 10 ha = score 2	
		10 to 100 ha = score 4	
		100 to 1,000 ha = score 6	
		Greater than 1,000 ha = score 12	
Number	How many infestations are there? Infestations are geographically distinct and not as feasible if crew have to pack up equipment and drive between infestations.	1 = score 0	**6**
		2 to 3 = score 3	
		Greater than 3 = score 6	
Site accessibility	What is the general accessibility of infestations?	Low (most sites difficult to access) = score 6	**0**

Factor	Feasibility of eradication question	Scores options for gross infestations e.g. "can we eradicate weed from the park?"	Score
	Consider terrain, ability to move through vegetation, travel times and seasonal difficulties (e.g. flooding).	Medium (most sites readily accessible) = score 3	
		High (all sites readily accessible) = score 0	
Detectability period	Is the weed conspicuous within the matrix of invaded vegetation? Score for the type of vegetation in which the weed would be expected to be least visible.	Yes, conspicuous (i.e. easy to see) stage lasting for:	**1**
		Less than 1 month = score 12	
		1 to 3 months = score 6	
		Greater than 3 months = score 1	
		No, i.e. always inconspicuous & hard to see = score 24	
Search/detection distance	For plants that reproduce by seeds or detachable vegetative propagules, how detectable is the species prior to reproduction? Score for the type of vegetation in which the weed would be expected to be least visible.	Difficult to detect (non-emergent from vegetation and with no distinctive features) = score 6	**0**
		Moderately easy to detect (either emergent or with distinctive features) = score 3	
		Very easy to detect (emergent and with distinctive features) = score 0	
Vegetative reproduction	Can the species reproduce through detachable vegetative propagules i.e. bulbils, aerial tubers, stem segments?	Yes = score 3	**3**
		No = score 0	
Pre-reproductive period	For species that reproduce by seeds or detachable vegetative propagules, what is the minimum length of the pre-reproductive period?	Less than 1 month = score 6	**6**
		1 to 12 months = score 4	
		1 to 2 years = score 2	
		Greater than 2 years = score 0	
Propagule longevity	What is the maximum longevity of seeds or detachable vegetative propagules? **	Greater than 10 years = score 6	**0 (default score)**
		5 to 10 years = score 4	
		2 to 5 years = score 2	
		Less than 2 years = score 0	
		Default in absence of information = score 4 for seed-producing species; score 0 for those producing vegetative propagules	
Treatments	How many treatments are required to control the largest plants? 'Largest plants' may be clones in vegetatively reproducing species.	Number of treatments = score n (where 'n' is the number of treatments)	**5**
	Does more than 10% of the total infestation occur in situations that require treatment methods that are more expensive than standard methods? For example, proximity to watercourses may limit use of herbicides.	Yes = score 3	**0**
		No = score 0	
Propagule dispersal	Potential for managing propagule dispersal. Affects ease of containment and area over with searching must be	Dispersal primarily abiotic (e.g. wind and/or water) or biotic (i.e. from living organisms) but not involving humans = score 6	**0**

Factor	Feasibility of eradication question	Scores options for gross infestations e.g. "can we eradicate weed from the park?"	Score
	conducted. Human-mediated dispersal should be easier to influence.	Dispersal occurs through a balanced mixture of human- and non-human-mediated modes = score 3	
		Dispersal primarily human-mediated (includes stock) = score 0	
	Total	**Add scores together**	**27**

** For more information on modelling persistence of seeds, see Long *et al*. (2015) and Panetta (2015).

Interpreting the feasibility of eradication score

The total score produced by the score sheet (Table 1 above) will range from two (2) for a 'good' scenario (i.e. more feasible to eradicate) to seventy-nine (79) or more for a 'bad' scenario (i.e. less feasible to eradicate) as illustrated in Figure 8 below. The lower the score, the more feasible eradication is. The higher the score, the more likely eradication will fail.

For the example in Table 1 above, we can see that for *Cylindropuntia pallida* at Ouyen State Forest, the recommendation is probably borderline feasible for eradication with a score of 27. The score indicates that the weed is at the 'more feasible' end of the feasibility of eradication spectrum. To be more meaningful, it should be compared to the score for other weeds at the same site.

The criteria in favour of feasibility of eradication in this example are: the site is easily accessible, the plant has a long detectability period, it is very easy to detect, the vegetative propagules have relatively short longevity, treatment methods have consistent costs across the site, and dispersal of propagules is primarily human-mediated.

The criteria against feasibility of eradication in this example are: the gross area of the infestation is over 100 ha, there are greater than 3 infestations, the species can reproduce through detachable vegetative propagules, the minimum length of the pre-reproductive period is less than a month, and at least 5 treatments are required to control the largest plants.

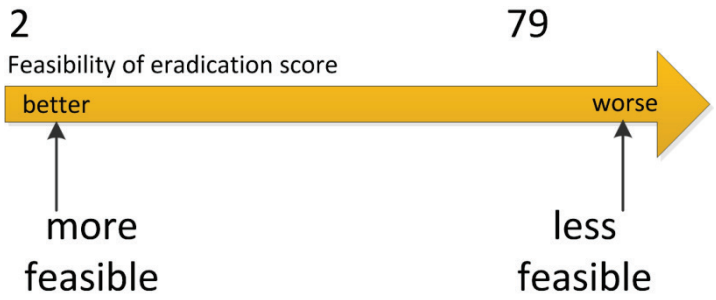


Figure 8 - Illustration to indicate the range and meaning behind the feasibility of eradication score.

Appendix 5 includes characteristics of 'more feasible to eradicate' weeds, and factors not thought important for local eradication.

Appendix 6 includes information on 'eradication syndromes' that can further refine feasibility assessments if required.

If eradication is not feasible

If eradication is not feasible, go back to the weed management matrix and consider the other management approaches which may be more appropriate e.g. containment or asset protection.

When dealing with more than one eradication candidate

If you are faced with a number of eradication candidates and you have to decide between them or decide which one to start with first, the weed management matrix, suitability for eradication, and feasibility of eradication sections should assist. If you are still trying to prioritise the candidates you have, the following may help.

Breathing space

If you need some breathing space before deciding, short-term actions to prevent a weed spreading can be completed e.g. removing and safely disposing of seed heads of a weed that only spreads by seeds. However, don't leave it too long or you may miss the next flowering and seeding.

Finding the right balance

It may be that a combination of different targets may produce the best results. Sometimes treating a combination of less serious risk weeds will give a better collective result than just treating one high risk weed. Consider the cost of treating each weed versus the risk rating of each. It's a bit like trading on the stock market, you have to find the right balance between maximising your return and minimising your risk (Extracts from ref by Andrew Matuszak viewed online 21/5/2015: http://economistatlarge.com/portfolio-theory/introduction-to-portfolio-theory). This is called the portfolio theory way of thinking or Markowitz's modern portfolio theory, which you can learn more about online if you wish.

Consider the easy targets – it may be that treating a medium-high risk weed with medium costs and good probability of success will be a better outcome than a high cost weed with less probability of success.

Making decisions can be tricky

As an illustration of how tricky these decisions can be, here is a scenario a public land manager may be faced with. Three weeds have been detected and the manager cannot afford to eradicate all of them:

- **Weed 1** is high risk, has short-lived, bird-dispersed seeds, but is present in difficult terrain, which means high costs and a distinct possibility that progress to eradication might be set back or eradication may be rendered unfeasible by seed dispersal from undetected plants. Summarised as high cost, high payoff if successful, unpredictable duration.
- **Weed 2** is medium/high risk, moderate cost, but has a long-lived seedbank, meaning that follow-up monitoring will be needed for many years. There is little public interest. Any hiatus in the program due to funding interruption or staff not being available will result in more seed set, extending the time to eradication. Summarised as moderate cost, medium/high payoff if successful, but the current manager will be long gone by the time eradication can be claimed.
- **Weed 3** is medium risk, the seedbank is short-lived and, as it is readily identifiable and present in easy terrain, there is potential for cost saving by involving volunteers. Summarised as low cost, medium payoff if successful, short duration and potential for some good publicity.

Which weed would you choose and why?

Some of these dilemmas could be resolved by developing policy positions that guide managers in relation to things such as preferred investment horizons and organisational tolerance for public criticism of unsuccessful eradication efforts.

What next?

Where are you up to?

At this stage you have decided how you will respond to which weeds. This will include which weeds are local eradication targets.

You must be sure that the weed(s) you plan to eradicate are suitable and feasible targets before proceeding.

Planning what to do next

If it is feasible to eradicate locally, the next step is to plan and undertake an eradication response. Use the following guide (see Figure 9) with the help of the WESI team (see Appendix 7):

Figure 9 - Planning what to do next.

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Appendix 1 - Decision making framework (including scenarios)

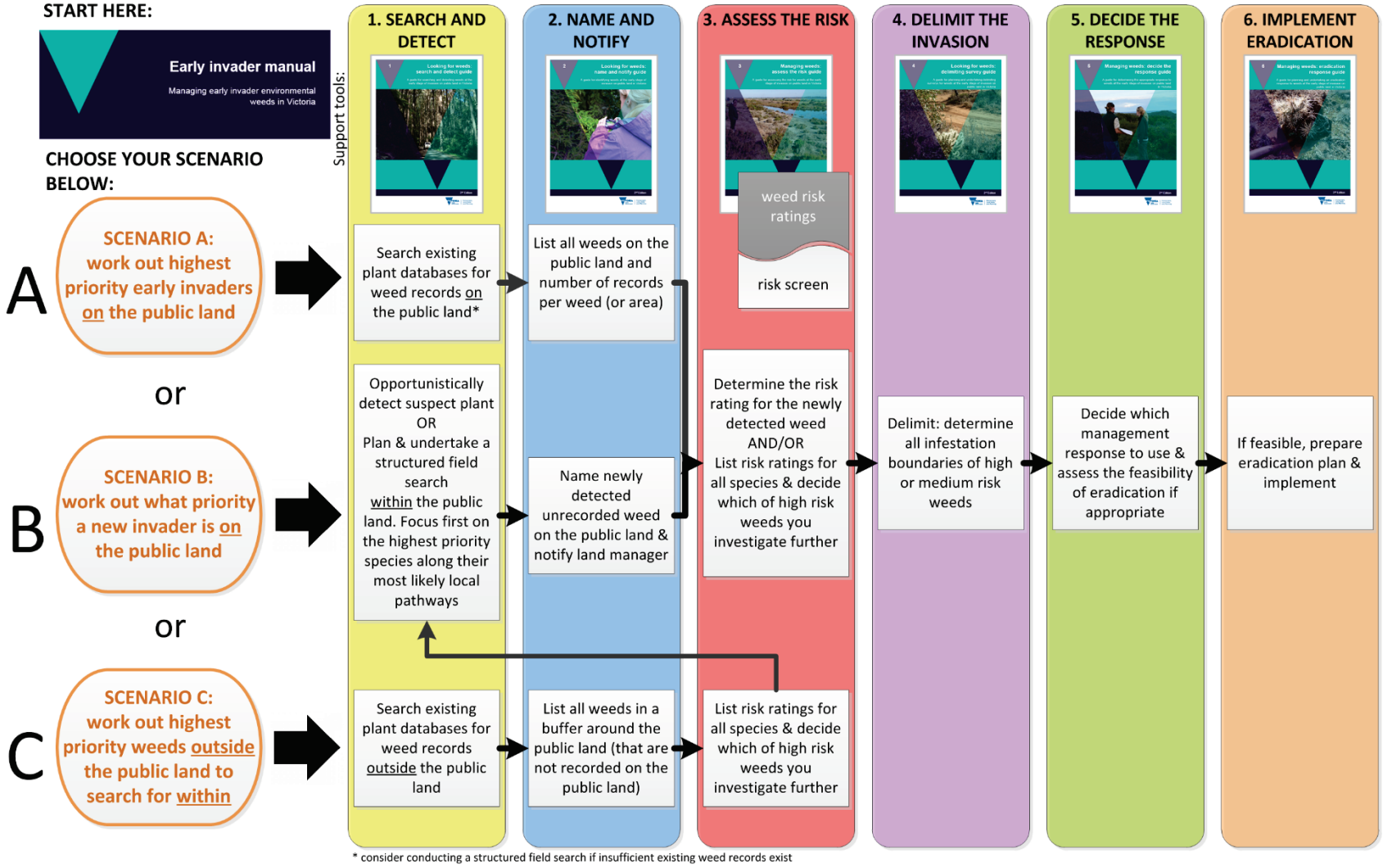


Figure 10 - This is the WESI decision making framework that guides the process for dealing with weeds at the early stage of invasion. This version illustrates three typical scenarios faced by public land managers.

Appendix 2 - Feasibility of eradication score sheet template

How to use the score sheet below for weeds at the early stage of invasion and under consideration for local eradication on public land:

1. Record the appropriate score for each question then sum the scores at the bottom of the table.

2. The score produced by using the table gives an indication of the comparative eradication effort i.e. the effort required to eradicate a weed from a particular place. It is only an estimate but can be a useful guide, especially when trying to determine if one weed is more feasible to eradicate than another. There is no cut-off or threshold score – you do as much as you can with the funding available.

3. Attach a copy of the completed score sheet to the appropriate record in the Spatial, Temporal, Activity Recorder (STAR).

Table 2 - Feasibility of eradication score sheet (based on the work of Panetta and Timmins (2004) and Dodd *et al.* (2015), with modifications according to Aaron Dodd, Kate Blood and Bec James).

Species:		**Name of assessor:**	
Location of weed:		**Date of feasibility assessment:**	

Factor	**Feasibility of eradication question**	**Score options for <u>gross</u> infestations e.g. "can we eradicate weed from the park?"**	**Score**
Area ##	What is the gross area of the weed infestation being assessed?	Less than 1 ha = score 0	
		2 to 10 ha = score 2	
		10 to 100 ha = score 4	
		100 to 1,000 ha = score 6	
		Greater than 1,000 ha = score 12	
Number ##	How many infestations are there? Infestations are geographically distinct and not as feasible if crew have to pack up equipment and drive between infestations.	1 = score 0	
		2 to 3 = score 3	
		Greater than 3 = score 6	
Site accessibility ##	What is the general accessibility of infestations? Consider terrain, ability to move through vegetation, travel times and seasonal difficulties (e.g. flooding).	Low (most sites difficult to access) = score 6	
		Medium (most sites readily accessible) = score 3	
		High (all sites readily accessible) = score 0	
Detectability period ##	Is the weed conspicuous within the matrix of invaded vegetation? Score for the type of vegetation in which the weed would be expected to be least visible.	Yes, conspicuous (i.e. easy to see) stage lasting for:	
		Less than 1 month = score 12	
		1 to 3 months = score 6	
		Greater than 3 months = score 1	

Factor	Feasibility of eradication question	Score options for gross infestations e.g. "can we eradicate weed from the park?"	Score
		No, i.e. always inconspicuous & hard to see = score 24	
Search/detection distance ##	For plants that reproduce by seeds or detachable vegetative propagules, how detectable is the species prior to reproduction? Score for the type of vegetation in which the weed would be expected to be least visible.	Difficult to detect (non-emergent from vegetation and with no distinctive features) = score 6	
		Moderately easy to detect (either emergent or with distinctive features) = score 3	
		Very easy to detect (emergent and with distinctive features) = score 0	
Vegetative reproduction	Can the species reproduce through detachable vegetative propagules i.e. bulbils, aerial tubers, stem segments?	Yes = score 3	
		No = score 0	
Pre-reproductive (juvenile) period	For species that reproduce by seeds or detachable vegetative propagules, what is the minimum length of the pre-reproductive period?	Less than 1 month = score 6	
		1 to 12 months = score 4	
		1 to 2 years = score 2	
		Greater than 2 years = score 0	
Propagule longevity	What is the maximum longevity of seeds or detachable vegetative propagules? **	Greater than 10 years = score 6	
		5 to 10 years = score 4	
		2 to 5 years = score 2	
		Less than 2 years = score 0	
		Default in absence of information = score 4 for seed-producing species; score 0 for those producing vegetative propagules	
Treatments	How many treatments are required to control the largest plants? 'Largest plants' may be clones in vegetatively reproducing species.	Number of treatments = score n (where 'n' is the number of treatments)	
	Does more than 10% of the total infestation occur in situations that require treatment methods that are more expensive than standard methods? For example, proximity to watercourses may limit use of herbicides.	Yes = score 3	
		No = score 0	
Propagule dispersal	Potential for managing propagule dispersal. Affects ease of containment and area over with searching must be conducted. Human-mediated dispersal should be easier to influence.	Dispersal primarily abiotic (e.g. wind and/or water) or biotic (i.e. from living organisms) but not involving humans = score 6	
		Dispersal occurs through a balanced mixture of human- and non-human-mediated modes = score 3	
		Dispersal primarily human-mediated (includes stock) = score 0	
	Total	**Add scores together**	

** For more information on modelling persistence of seeds, see Long *et al*. 2015, and Panetta 2015.

Information that needs to be collected in the field for this site.

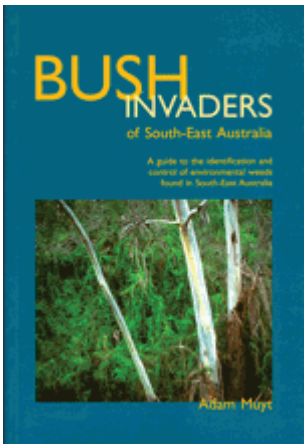
Definitions of terms used in this score sheet appear in the glossary.

Appendix 3 - Information sources

There are many tools and resources about weeds. Here is a small selection.

Field guides

Bush invaders of South-East Australia: a guide to the identification and control of environmental weeds found in South-East Australia.



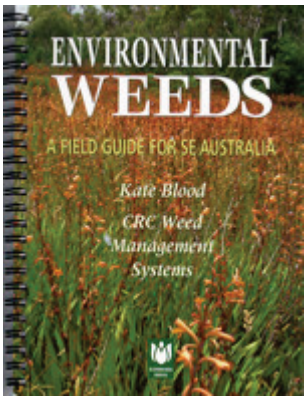
Author: Adam Muyt

Publisher: R. G. & F. J. Richardson.

Publication date: 2001.

Contains colour photographs, diagnostic features for identification, how they spread, similar looking plants and management information.

Environmental weeds: a field guide for SE Australia.



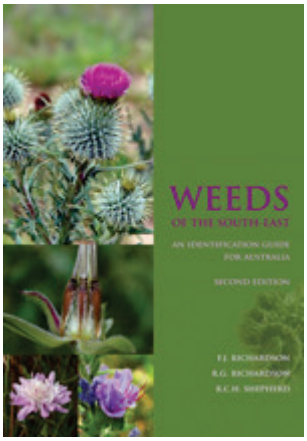
Author: Kate Blood

Publisher: Bloomings Books, Melbourne.

Publication date: 2001.

Contains colour photographs, descriptions for identification, look-alikes, how they spread, ecology, reporting sheet to copy and distribution maps.

Weeds of the south-east: an identification guide for Australia (3rd edn).



Authors: F. J. Richardson, R. G. Richardson & R. C. H. Shepherd.

Publisher: R. G. and F. J. Richardson.

Publication date: 2016.

Contains colour photographs and includes brief descriptions and summary distribution information.

Flora of Victoria (Volumes 1-4).

Editors: D. B. Foreman and N. G. Walsh; and N. G. Walsh and T. J. Entwisle.

Publisher: Inkata Press.

Publication dates: Between 1993 and 1999.

Large books with botanical descriptions and keys for indigenous and introduced plants. Some line drawings, distribution maps and glossary of botanical terms. Updated information is now available at VICFLORA: http://data.rbg.vic.gov.au/vicflora/

Other specialist guides

Sainty, G. R. and Jacobs, S. W. L. (2003) *Waterplants in Australia. A field guide* (4th edn). Sainty and Associates, NSW.

Hosking, J., Sainty, G. and Jacobs, S. (2006) *Alps invaders. Weeds of the Australian high country* (2nd edn). Australian Alps Liaison Committee, Canberra.

Matters, J. and Bozon, J. (1995) *Spotting soil salinity: A Victorian field guide to salt indicator plants*. Department of Conservation and Natural Resource, Melbourne.

People, social media and networks including weed ID network

Often the best information is nearby, especially when it comes to when weeds arrived and where they occur. Tap into the knowledge of people by contacting them directly. Ask local DELWP, Department of Economic Development, Jobs, Transport and Resources (DEDJTR (to be replaced by Department of Jobs, Precincts and Regions (DJPR) on 1 January 2019)) Agriculture Victoria or Parks Victoria staff for information. Contact your Catchment Management Authority, local governments, consultants and contractors. Tap into local community networks, including field naturalists, friends groups, Landcare groups, conservation groups, Weed Society of Victoria, garden clubs and horticultural groups etc.

Connect with others through social media e.g. Facebook, Twitter, Instagram, and your agency's internal social media e.g. Yammer for DELWP. Try search terms and hashtags such as #invasivespecies #invasiveplants #weeds (but be prepared for drug related material) #weedID #plantID. There are a number of Australian state or regionally-based groups on Facebook including 'The Weed Society of Victoria Inc'. More information on the use of social media for sharing information on invasive species can be found in Blood, 2016.

The WESI team is utilising social media for weed identification (weedID) support using the #weedID search term/hashtag.

There are internet-based networks of weed practitioners such as:

Enviroweeds

The ENVIROWEEDS listserver was created by the Cooperative Research Centre for Australian Weed Management (Weeds CRC) to help distribute and discuss information on the management of environmental weeds in natural ecosystems mainly in Australia. The Weeds CRC no longer exists but the listserver is still hosted by the University of New England. Participants can share information, ask questions, participate in discussions and respond to the queries of others.

The audience is those who are managing natural ecosystems, whether on private or public land and water, or those working with environmental weed information.

You can subscribe for free at https://mail.une.edu.au/lists/cgi-bin/listinfo/enviroweeds

ALIENS-L

ALIENS-L is the mailing list of the Invasive Species Specialist Group (ISSG) (www.issg.org) of the International Union for Conservation of Nature (IUCN) Species Survival Commission. The group aims to "reduce the threats posed by invasive species to natural ecosystems and their native species, through increasing awareness of invasive species and means of controlling or eradicating them". This list is a contribution to that mission. It allows users to freely seek and share information on invasive species and the threats which they pose to the biodiversity of our planet.

The ISSG is a worldwide network of experts on the conservation impacts of invasive species. Membership is by invitation, but it is not necessary to be a full member of the group to contribute to the cause of reducing conservation threats posed by invasive species.

ISSG provides advice on threats from invasive species and control or eradication methods to IUCN members, conservation practitioners, and policy makers. The group concentrates on reducing or preventing the adverse effects of alien invasions on conservation values.

The list homepage: https://list.auckland.ac.nz/sympa/info/aliens-l

General information about mailing lists: https://list.auckland.ac.nz/sympa/help/introduction

Mobile apps

The development of mobile applications (apps) for mobile phones and tablets is a rapidly growing area. Mobile apps are useful to have in the field where there is internet connectivity. Apps can assist with field data collection, mapping and identification.

On-line information

Agency internal information on weeds, their distribution and management

Spatial, Temporal, Activity Recorder (STAR) (for DELWP and Parks Victoria): https://star.biodiversity.vic.gov.au (performs best in Google Chrome)

Victorian Biodiversity Atlas (VBA): https://www.environment.vic.gov.au/biodiversity/victorian-biodiversity-atlas and for log-in: https://vba.dse.vic.gov.au/vba/#/

Environmental Information System (EIS) (access through Parks Victoria)

Bioweb, Bioweb2, MAX (access through Agriculture Victoria)

Crown Land Manager (CLM) Pest Infestation Sites (access through DELWP)

Local databases, spread sheets, maps, Geographic Information System (GIS) layers, works plans of weed infestations, note books, filing systems, and registry files

Local reserve, forest, and park etc. management plans that may include weed lists

Plant Identification and information

Weeds in Australia (Federal Government)
http://www.environment.gov.au/biodiversity/invasive/weeds/

Weed information notes including environmental weeds - Agriculture Victoria:
http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/weeds/a-z-of-weeds

Various keys including weeds at Lucid: https://keyserver.lucidcentral.org/

Fact sheets on over 1,000 species: https://keyserver.lucidcentral.org/weeds/data/

Lucid key to Environmental Weeds of Australia (originally developed with CRC Weed Management & updated by Qld Herbarium) is online Apps iOS - https://itunes.apple.com/au/app/environmental-weeds-australia/id898685476?mt=8 ; Android - https://play.google.com/store/apps/details?id=org.lucidcentral.mobile.ewa&hl=en

Weeds of National Significance (WONS): http://weeds.ala.org.au/WoNS/ and http://www.environment.gov.au/biodiversity/invasive/weeds/weeds/lists/wons.html

National Herbarium of Victoria - Identification (some services for fee) and information services. Herbarium specimens and records viewable through AVH & ALA otherwise by appointment with the Herbarium: https://www.rbg.vic.gov.au/science/herbarium-and-resources/identification-and-information-services

VICFLORA – Flora of Victoria, comprehensive and current guide to the wild plants of Victoria including weeds. Includes plant profiles, identification tools and illustrations:
https://vicflora.rbg.vic.gov.au/

Victorian Noxious weed status - Weeds declared in Victoria under the *Catchment and Land Protection Act 1994* (CaLP Act), are listed at the Agriculture Victoria website: http://economicdevelopment.vic.gov.au/. Information is also available through the Customer Service Centre on 136 186.

Local Government Resources - Use your favourite search engine to search for local government brochures and field guides.

Weed risk and biodiversity modelling

Advisory list of environmental weeds in Victoria - https://www.environment.vic.gov.au/invasive-plants-and-animals/weed-risk-ratings or web search for 'early invaders Victoria weed'.

Victorian environmental weed risk database – as above for advisory list.

Weed risk assessments - available on Victorian Resources Online (VRO) (see "Managing weeds: assess the risk guide" for more detail on risk ratings): http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/invasive_plants_common_a

Weed Futures - decision-support tool to interrogate profiles for over 500 species within Australia and assess weed threats for regions of interest under current and predicted future climates: http://weedfutures.net/

NatureKit - tool to map and report on Victoria's biodiversity values and investment prospects. Includes NaturePrint and Strategic Management Prospects: http://maps.biodiversity.vic.gov.au/viewer/?viewer=NatureKit

Weed lists and distribution

VICFLORA – Flora of Victoria, comprehensive and current guide to the wild plants of Victoria including weeds. Includes plant profiles, identification tools and illustrations: https://vicflora.rbg.vic.gov.au/

NatureKit - tool to map and report on Victoria's biodiversity values and investment prospects: http://maps.biodiversity.vic.gov.au/viewer/?viewer=NatureKit

Victorian Biodiversity Atlas (VBA): https://www.environment.vic.gov.au/biodiversity/victorian-biodiversity-atlas and for log-in: https://vba.dse.vic.gov.au/vba/#/

Australia's Virtual Herbarium (AVH): http://avh.chah.org.au/

Atlas of Living Australia (ALA): http://www.ala.org.au/

Flora Information System (FIS) - available from Viridans Pty Ltd.

Global Biodiversity Information Facility (GBIF): http://www.gbif.org/

Names and nomenclature

VICFLORA – Flora of Victoria, comprehensive and current guide to the wild plants of Victoria including weeds. Includes plant profiles, identification tools and illustrations: https://vicflora.rbg.vic.gov.au/

Australian Plant Name Index (APNI): http://www.anbg.gov.au/apni/

Australian Plant Census (APC): http://www.anbg.gov.au/chah/apc/

International Plant Names Index (IPNI): http://www.ipni.org/ipni/plantnamesearchpage.do

More useful plant name links here: https://www.anbg.gov.au/cpbr/databases/names.html

Grass information

Grassbase the Online World Grass Flora: https://www.kew.org/data/grasses-db.html

AusGrass2: http://ausgrass2.myspecies.info/

Opuntioid Cacti information

Managing Opuntioid Cacti in Australia manual and field identification guide: https://www.agric.wa.gov.au/invasive-species/opuntioid-cacti-best-practice-control-manual

Opuntioid Cacti resources: http://weeds.ala.org.au/WoNS/opuntioidcacti/

Australian Invasive Cacti Network: http://www.aicn.org.au/

Global working group on the management of cactus species: http://academic.sun.ac.za/cib/projects/cactuswg/invasivecactus.asp

Other resources

Global compendium of weeds (3rd edition) has over 3,000 pages and there are several sources of this document:

https://www.cabi.org/isc/FullTextPDF/2017/20173071957.pdf or

https://www.dpaw.wa.gov.au/images/documents/plants-animals/plants/weeds/Compendium_3rd_Edition_2017.pdf or

https://nla.gov.au/nla.obj-512788350/view

VicVeg online: http://www.vicveg.net.au/vvInfo.aspx

BioControl Hub: https://biocollect.ala.org.au/biocontrolhub

Table 3 - Additional databases and websites that can be useful for finding information about the biology and ecology of different weed species. Most of this material is abstracted from the revised National Post-border Weed Risk Management Protocol (in preparation).

Data sources	Data description	Custodians or contacts
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/
Hawaiian Ecosystems At Risk website (HEAR)	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
Pacific Island Ecosystems at Risk website (PIER)	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

Appendix 4 - Wellbeing, safety and hygiene for field work

Wellbeing and safety

Refer to your agency's Occupational Health and Safety (OH&S) requirements for personal protective equipment and safety requirements. Items that should be considered include:

- first-aid kit and snake bite kit;
- personal protective equipment;
- satellite phone and emergency position-indicating radio beacon (EPIRB) if in remote locations.

Consider these points when you are planning and conducting field work:

- Avoid sun damage to skin – wear appropriate clothing, broad-brimmed hat, gloves, sunscreen, and sunglasses.
- Avoid field work on days of extreme fire danger.
- Be aware of flood and other emergency and weather warnings for the area and take appropriate precautions.
- Have a safety plan and reporting procedure in place for working remotely (refer to your agency's OH&S guidelines).
- When working near roadsides, park safely and wear high visibility clothing such as a reflective vest.
- Wear gaiters and carry a snake bite kit and know how to use it.
- Wear appropriate protective clothing when handling weeds. Be aware of plants which have:
    - spines or barbs that may have sheaths, toxins or irritants. Avoid stick injuries and treat punctures immediately.
    - sap that can cause skin irritation immediately or after exposure to sunlight.
    - fine hairs that can cause skin irritation and become lodged in clothing.
    - pollen and perfumes that can cause allergic reactions including respiratory irritation and hayfever.
- If working with cacti, carry pliers to remove cacti spines from footwear. Always check the back of boots before crouching down. Some cacti have spines with sheaths that remain in the body when the spine is removed. The "Managing Opuntioid cacti in Australia" manual has a chapter on safety and welfare (Sheehan and Potter 2017).
- Seek prompt medical advice if reactions, injuries or infections occur.

Hygiene

It is very important not to spread weeds, pests, wildlife diseases, soil-borne and plant-borne diseases between and within sites. Examples of things that may spread other than weeds include soil and plant-borne pathogens such as Phytophthora, Myrtle Rust, Chytrid fungus of frogs, and crazy ants. Consider these hygiene points when you are planning and conducting field work and check your agency's hygiene protocols:

- Carry a hygiene cleaning kit with instructions in vehicles, and a sealable container (e.g. plastic bottle with screw-top lid) in which to place loose or seeds removed from clothing for later safe disposal.
- Wear cotton clothing that seeds do not readily adhere to and avoid cuffs on trousers and shorts.

- Wear gaiters over socks and boots.
- Clean footwear and clothing including seeds in laces and socks, and soil on soles before and immediately after a site visit.
- Avoid placing carry bags and packs on weeds that are in seed.
- Regularly check camera bags and clothing pockets for seeds.
- Plastic sample bags can build up static electricity to which weed seeds can readily adhere.
- Avoid driving vehicles into weed infestations and check and clean the vehicle regularly including within the cabin and boot or tray.
- Consider undertaking WeedStop training to maintain suitable vehicle hygiene standards.
- Ensure other staff and contractors conducting field work are following appropriate hygiene standards.
- Be aware that the transportation of plant propagules of declared noxious weeds without a permit is prohibited. If collection of a sample or herbarium specimen is required for identification purposes, contact 136 186 for further advice.
- Companion and conservation working dogs readily pick up and spread weed seeds on their coat and between their toes.
- Consider using a footbath before entering and leaving wetland areas to reduce the risk of spreading Root Rot (*Phytophthora cinnamomi*) or frog disease, Chytrid fungus (*Batrachochytrium dendrobatidis*).

Support

Working with invasive species can be overwhelming at times. Seek help if you are feeling down or overwhelmed. Check in with your local workplace peer support person, OH&S person or contact:

Beyond Blue: www.beyondblue.org.au 1300 224 636

Lifeline Australia: www.lifeline.org.au 13 11 14

Appendix 5 - Characteristics of 'more feasible to eradicate' weeds

The table below (Table 4) can help highlight weeds that are more or less feasible to eradicate.

Table 4 - General characteristics that can indicate more or less feasible to eradicate (based on the work of Panetta and Timmins (2004) and Dodd *et al.* (2014), with modifications according to Kate Blood and Bec James).

Characteristic	What is more feasible to eradicate?	'Good or better' scenario i.e. more feasible to eradicate	'Bad or worse' scenario i.e. less feasible to eradicate
Infested area	Smaller area	Small gross area i.e. under 1 ha	Greater than 1,000 ha
Number of infestations	Fewer infestations	One infestation	More than three infestations
Site accessibility	Readily accessible sites	All sites readily accessible	Most sites difficult to access
Detectability period or Conspicuousness	Conspicuous over a long period	Species conspicuous and easy to see over an extended period i.e. over more than three months	Always inconspicuous and hard to see
Detection distance or Detectability prior to reproduction	Very easy to detect prior to commencing reproduction	Very easy to detect (emergent and with distinctive features) prior to it commencing reproduction (prior to reproductive maturity)	Difficult to detect (non-emergent from vegetation and with no distinctive features) prior to it commencing reproduction (prior to reproductive maturity)
Vegetative reproduction	Cannot reproduce vegetatively	Cannot reproduce through vegetative reproduction	Can reproduce through vegetative reproduction
Minimum pre-reproductive period	Longer pre-reproductive period	Takes a long time to reproduce i.e. takes more than 2 years	Reproduces quickly i.e. takes less than 1 month
Maximum propagule longevity	Propagules remain viable for 2 years or less	Propagules remain viable for a short time i.e. less than 2 years	Propagules remain viable for a long time i.e. more than 10 years
Treatments for largest plants	Single treatment to control the largest plants	One treatment required to control the largest plants	Many treatments required to control the largest plants

Characteristic	What is more feasible to eradicate?	'Good or better' scenario i.e. more feasible to eradicate	'Bad or worse' scenario i.e. less feasible to eradicate
Treatment expense	Fewer of the infestations require expensive treatment	Less than 10% of total infestations require more expensive treatment procedures than standard methods	More than 10% of total infestations require more expensive treatment procedures than standard methods
Propagule dispersal management	Mainly human-mediated dispersal	Dispersal mainly human-mediated (including stock)	Dispersal mainly abiotic (e.g. wind &/or water) or biotic but not involving humans

Factors not thought important for local eradication

This guide is about local eradication targets for public land within Victoria. As such at the local scale, these factors are thought to be relatively unimportant (Dodd *et al.* 2014):

- climate suitability - assume that if the plant is growing on the public land then it has suitable growing conditions for growth;
- land use; and
- general accessibility – this is related to the distance to the nearest manager (not ease of access to public land).

Appendix 6 - Eradication feasibility further explained using ‘eradication syndromes’

Eight ‘eradication syndromes’ have been described in detail in Panetta (2015) using time to maturity, seedbank persistence and the type of dispersal. For each syndrome, a relative eradication feasibility is indicated.

The eight syndromes range between highest and lowest feasibility of eradication:

- highest feasibility includes plants that have long juvenile periods and low seedbank persistence, with short-distance and/or human-mediated dispersal
- lowest feasibility includes plants that have a short juvenile period and high seedbank persistence, with abiotic or non-human-mediated biotic dispersal. This includes a number of aquatic perennials that can be dispersed over large distances by floodwaters

Appendix 7 - Further contacts

Contact the WESI project team

The WESI project team can assist with determining feasibility of eradication and working out what to do next.

Having some information ready when making contact will make it easier for the WESI project team to help you:

- Your name and contact details (email, mobile phone etc.)
- The botanical name of the weed(s) being considered for eradication
- Where and when the weed was detected (location name, land tenure, directions, and GPS reading)
- Any notes on what it looks like and the situation it is growing in e.g. growing in sand or clay or in a water body.
- Observations about how the weed may have got there, what is spreading it and how far it has spread. An estimate of how many plants there are and the area covered
- What are its impacts and what are the biodiversity values under threat?

Have you taken photographs of plant features and landscape that can be emailed? Electronic images can be emailed to the WESI project team to assist with identification (if images are large, only one image should be attached to each email). Alternatively, let WESI know that you have placed images in the WESI folder on the DELWP corporate drive statewide: L:\Department Business Share\WESI early invaders

For assistance with a possible weed at the early stage of invasion contact the WESI project team.

Bianca Gold

bianca.gold@delwp.vic.gov.au

Kate Blood

kate.blood@delwp.vic.gov.au

Phone via the Customer Service Centre 136 186.

The WESI project has a seasonal newsletter “Early invader update” that you can receive for free. Contact us to subscribe.

The project team is active on social media. Search for handle @weedyk8 and hashtags #WESIProj #weedID #invasivespecies

Agency contacts

Victorian Government Customer Service Centre: 136 186 (for DELWP and DEDJTR/DJPR Agriculture Victoria)

https://www.environment.vic.gov.au/

https://economicdevelopment.vic.gov.au/

Parks Victoria: 13 1963

http://parkweb.vic.gov.au/

Glossary and abbreviations

Glossary

Abiotic - Not involving living organisms (Beentje 2010).

Asset-based approach - Involves prioritising control actions for a number of threats, based on the relative value of identified assets that will be protected by the actions. The aim of prioritisation is to maintain the viability of important environmental assets and optimise outcomes for asset protection and management (Victorian Government 2010).

Biodiversity - The variety of life forms: the different plants, animals and microorganisms, the genes they contain and the ecosystems they form (Victorian Government 2010).

Biodiversity asset - The area (e.g. nature reserve or park) that is being managed to preserve biodiversity values (Panetta 2016).

Biotic - Biotic factors are environmental influences that arise from the activities of living organisms (as distinct from e.g. climatic factors) (Abercrombie 1973).

Budbank, bud bank - The viable growing points underground (other than seeds) that can grow into new plants e.g. bulbs, rhizomes.

Bulbil - A small bulb produced on a plant stem above ground that can grow into a new plant. A detachable propagule.

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 (Panetta 2016).

Control - To implement actions that reduce the effects of a pest organism where it occurs. For weeds, a wide range of treatment methods are used for control, generally falling into the categories of mechanical, chemical and biological control (Panetta 2016).

Decision making framework - Information organised in such a way to lead the user through a logical step-by-step process to make decisions (Blood and James 2016).

Delimit, delimiting survey, delimitation - 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 (Panetta 2016).

Detectability period - The time during which something is likely to be found i.e. because it is more visible during this time.

Detection distance, search distance - The distance over which a weed is detectable prior to reproduction, when a search is undertaken in particular terrains and vegetation types.

Early intervention - The timely action to prevent a small problem becoming a large one.

Early invaders, early weed 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 (Panetta 2016).

Early stage of invasion - See ‘early invader’.

Ecosystem - An ecosystem consists of a diverse and changing set of living organisms that form a community, interacting with each other and with the physical elements of the environment in which they are found (DSE 2009).

Engagement - Planned process with the specific purpose of working with identified groups of people to address issues affecting their well-being. The broad interactions between people including one-way communication, information delivery, consultation, involvement, collaboration,

and empowered action. Can cover extension, communication, education, public participation, and working in partnership (Riches 2005 book 1).

Environmental weed - Exotic or Australian native plant growing beyond its natural range that has, or has the potential to cause, a detrimental effect on natural values (DSE 2009).

Eradication - The elimination of every single individual (including propagules) of a species from a defined area in which recolonisation is unlikely to occur (Panetta 2016).

Eradication effort - The effort required to eradicate a weed from a particular place. Estimates of eradication effort are by nature crude, but can be useful guides, especially when trying to determine if one weed is more feasible to eradicate than another.

Extirpation - Denotes local, as opposed to global, elimination of a species (Panetta 2007). For this guide series 'park-scale eradication' is used instead.

Feasibility of eradication - The probability that eradication will be achieved. All other factors being equal, a potential target that has a low feasibility of eradication will require considerably more effort to eradicate than one having a high eradication feasibility. Ultimately, the assessment of eradication feasibility must take into account the amount of resources that is likely to be available (Panetta 2009).

Feasibility of eradication score sheet - A score sheet consisting of a number of questions that calculates the probability that eradication will be achieved.

Gross infestation area - The larger infested area including the net areas that require treatment plus the surrounding area that must be searched in return trips following treatments (Panetta and Timmins 2004).

Hygiene - For weed practitioners, hygiene relates to the cleaning of equipment, machinery, vehicles, personal clothing and footwear etc. to avoid spreading weed propagules, pests, wildlife diseases, soil-borne and plant-borne diseases within and between sites (Blood and James 2016).

Identification - The process of naming a plant, if not instantly from your knowledge, then through a more structured process, either by using a botanical key or other reference. Until a plant identification has been verified through the collection and submission of a specimen to the National Herbarium of Victoria (Herbarium), a proposed or preliminary name can be called a ‘provisional’ identification (Blood and James 2016).

Indigenous - Native to the area; not introduced (FloraOnline 2010).

Invasion curve, biosecurity curve - A graphical representation illustrating the phases a weed goes through as it arrives and invades an area.

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).

Invasive species - A species occurring, as a result of human activities, beyond its accepted normal distribution and which threatens valued environmental, agricultural or other social resources by the damage it causes (Victorian Government 2010).

Juvenile period (synonym pre-reproductive period) - The time between when a plant appears as a seedling and when it first produces propagules (Panetta 2016).

Land tenure - The status of the land e.g. private or Crown land.

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 (Panetta 2016).

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 (Panetta 2016).

Net infested area, net infestation - The area requiring actual treatment (Panetta and Timmins 2004).

Pathogen - An infectious agent such as a virus, bacterium, prion, fungus, viroid, or parasite that causes disease in its host (Reference viewed online 3/9/2015: https://en.wikipedia.org/wiki/Pathogen).

Pathway - The combined processes that result in, or drive, the introduction of non-indigenous species from one geographical location to another (Panetta 2016).

Portfolio theory, Markowitz's modern portfolio theory - Finding the balance between maximizing your return and minimizing your risk (Extracts from ref by Andrew Matuszak viewed online 21/5/2015: http://economistatlarge.com/portfolio-theory/introduction-to-portfolio-theory)

Prevention - Is the act of preventing, to keep from occurring (Delbridge *et al*. 1998).

Probability - The likelihood that something will occur.

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 (Panetta 2016).

Public land - Land set aside for the use and benefit of the community/public e.g. State forest, national park, public park.

Reproductive escape - The production of seeds or other propagules by the target species during the course of an eradication program (Panetta 2007).

Reproductive maturity - The time at which a plant can start producing propagules.

Response clock - A way of timing how long it takes to exhaust a seedbank or budbank before a weed can be assessed as locally eradicated. If the plant has the chance to produce propagules, the response clock has to go back to zero and counting started again.

Rhizome - An underground stem, usually growing horizontally (FloraOnline 2010). A rhizome is an example of a joined vegetative propagule.

Risk - The chance of something happening that will have an impact on objectives. NOTE: The level of risk (e.g. high, medium or low) is defined by the particular method being used. Estimating the level of risk requires an objective, evidence-based consideration of the likelihood and consequences of a particular set of circumstances (Victorian Government 2010).

Risk rating - A generic term used to provide, in this case, an indication of the level of threat posed by a weed in Victoria (Blood *et al*. 2016).

Search, searching - The act of looking for something.

Seedbank, seed bank - The accumulated viable seed buried in the soil or in the leaf litter on top of the soil.

Site - The boundary of the area of interest for the search, survey or treatment within the broader reserve, State forest, or national park etc. It may be defined by vegetation communities, land type most susceptible to invasion, roads or river boundaries that divide the land parcel into more manageable areas (Sheehan *et al*. 2016).

Stolon - A stem that is usually growing horizontally above the ground, roots forming at the nodes and a new plant forming at the tip. Stolons are a joined vegetative structure propagule.

Suitability for eradication - The status of a weed with regard to a range of criteria, including social and political support, prevention of further arrival, effective treatment options, estimated effort for eradication, cost-benefit analysis and the availability of sufficient resources for the duration of a proposed eradication effort (based on Panetta and Timmins 2004).

Threatening process - A physical process that increases the probability that biodiversity values will decline at the local, regional, national or global level (DSE 2009).

Treatment - Is a technique applied to a weed to kill or reduce the vigour of the weed and/or its propagules.

Vegetative structures, joined or detachable - 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 or joined 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 (Panetta 2016).

Weed - Plants (not necessarily alien) that grow in sites where they are not wanted and which usually have detectable economic or environmental effects (synonyms: plant pests, harmful species, problem plants) (Richardson *et al*. 2000).

Weed management matrix - A matrix that brings together weed distribution information from delimiting surveys and weed risk ratings to recommend a preferred management approach for different situations.

Weed Risk Assessment - An evidence-based process estimating the relative weed risk of plant species, based on their biological characteristics, impacts on agriculture, the environment and human health, and the ratio of the species' present and potential distribution (Victorian Government 2010).

Weed risk matrix - A matrix that brings together Weed History and Local Performance to recommend either to delimit the species (as a precursor to further determination of eradication feasibility) or to monitor it in the future to detect changes in its invasiveness and/or impact, should these occur (Blood *et al*. 2016).

Weeds at the early stage of invasion - See 'early invaders'.

Abbreviations

ALA	Atlas of Living Australia
APC	Australian Plant Census
APNI	Australian Plant Names Index
app	application
AVH	Australia's Virtual Herbarium
CaLP	Catchment and Land Protection
CLM	Crown Land Manager
CSC	Customer Service Centre
DEDJTR	Department of Economic Development, Jobs, Transport and Resources (to be replaced by DJPR on 1 January 2019)
DELWP	Department of Environment, Land, Water and Planning
DJPR	Department of Jobs, Precincts and Regions (to replace DEDJTR 1 January 2019)
DMF	decision making framework
Ecodev	URL abbreviation for DEDJTR
EIS	Environmental Information System
EPIRB	Emergency Position Indicating Radio Beacon
et al.	et alia
FIS	Flora Information System
GBIF	Global Biodiversity Information Facility
GIS	Geographic Information System
ha	hectare
id, ID	identification
IPNI	International Plant Names Index
I-SPEI	Invasive Species Prevention and Early Intervention
ISSG	Invasive Species Specialist Group
IUCN	International Union for Conservation of Nature
OH&S, OHS	Occupational Health and Safety
STAR	Spatial, Temporal, Activity Recorder
URL	Uniform Resource Locator
VBA	Victorian Biodiversity Atlas
VRO	Victorian Resources Online
Weeds CRC	Cooperative Research Centre for Australian Weed Management
WESI Project	Weeds at the Early Stage of Invasion Project
WONS	Weed of National Significance

List of figures and tables

www.environment.vic.gov.au/invasive-plants-and-animals/early-invaders