Early intervention of new and emerging weeds

A South Australian handbook

Government of South Australia

For more weed resources and information go to

pir.sa.gov.au/weeds

Templates and resources available online include:

Resources document, Eradication response plan template, Search plan template, Field recording template for weed searches and Field recording template for opportunistic sightings and herbarium specimens

Early intervention of new and emerging weeds

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Cover photo: Lone *Cylindropuntia tunicata* plant detected at farm boundary (photo by Shannon Robertson).

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Introduction

Managing land, whether it be private property, public land, native vegetation or an agricultural system, involves balancing many requirements of which weeds are only one.

This handbook is full of different 'tools' and hints to help you through the weed management process.

Start at the beginning and work your way through the step-by-step process or browse your topic of interest.

Whilst this handbook leads you through the process of eradicating weeds at the early stage of invasion, generally eradication is not the aim for most weeds, so it is essential that the handbook be used in conjunction with long-term observations, learned skills and decisions based on local conditions.

This handbook is to help, not substitute, these important skills.

About this handbook

Finding and destroying weeds at their earliest stages of invasion is the best way to prevent the next widespread weed. This approach is referred to as 'early intervention'. Increasingly around the world, the benefits of prevention and 'nipping new weeds in the bud' are being appreciated.

The aim of this handbook is to guide land managers through the many decisions faced when:

- identifying weeds at the early stage of invasion
- determining whether they are suitable eradication targets
- providing advice on how to plan and execute an eradication response.

Only a small percentage of weeds are suitable for local eradication; therefore an eradication response should only be instigated if it is likely to succeed. At each step along the way, certain weeds may be identified as unsuitable for local eradication and a different management approach taken.

This handbook can help you decide if certain weeds are realistic local eradication targets by:

- determining weed risk
- outlining factors influencing eradication success
- helping to identify suitability for eradication.

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 land managers, whether they do the work in the field, design the work or authorise the delivery of the work.

This handbook can help land managers improve their knowledge about the highest risk weeds, learn how to search and identify them, learn how to determine where the infestation boundaries are, work out which management approach is best and respond with local eradication, where feasible.

What is ‘the early stage of invasion’?

In this handbook, we refer to ‘weeds at or in the early stage of invasion’. Weeds at the early stage of invasion are plants that have naturalised and started to spread. Naturalised plants are non-indigenous species that sustain self-replacing populations for several life cycles without intervention by people.

When spread has just begun, these plants are not widespread and are generally encountered only by chance, unless specifically targeted by search efforts. Coordinated management intervention, such as eradication or containment, is feasible at this stage of invasion.

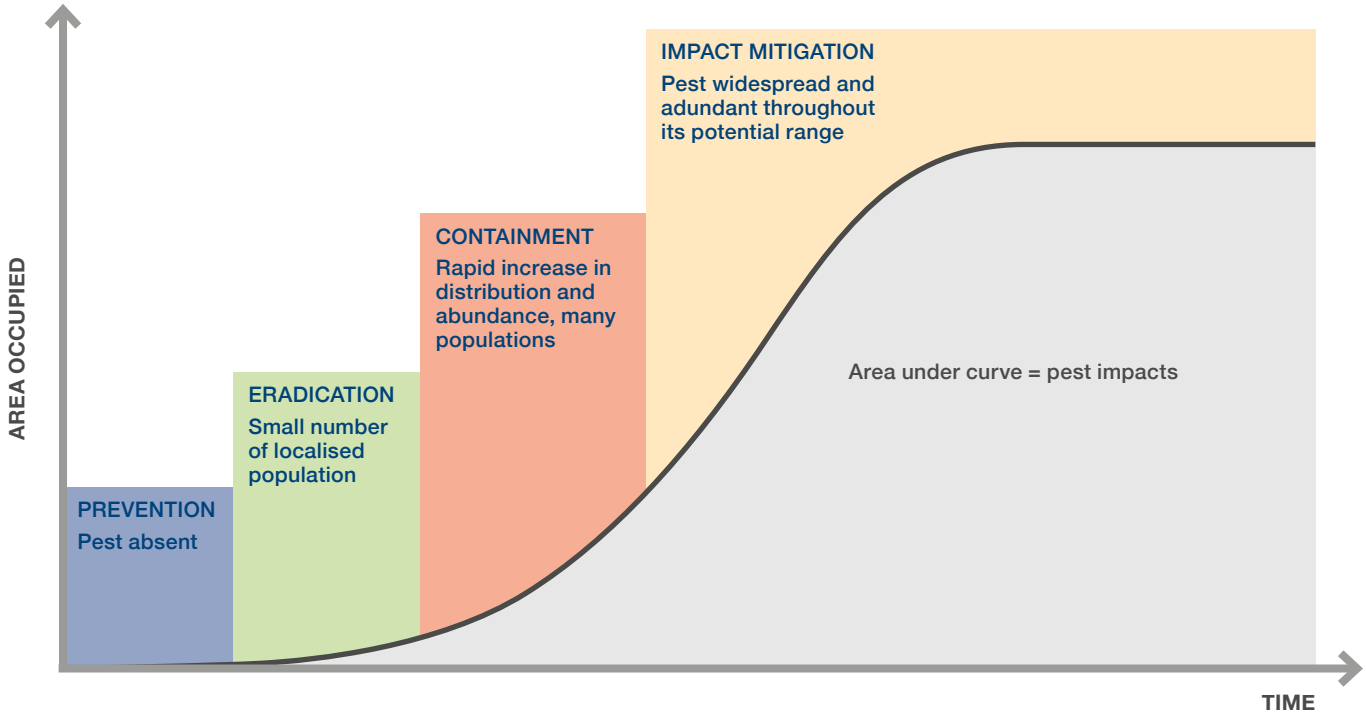
Understanding your weed management options

How do I know what is best for my situation?

Often when people begin eradicating a weed, they are actually just controlling or suppressing it. This still provides benefits, such as preventing weed spread (containment) or reducing negative impacts to agriculture or the environment (asset protection) but it’s not technically eradication.

Localised eradication is only suitable in certain situations, and there are alternative management approaches more suited to other circumstances.

Figure 1 – The invasion curve illustrates how management approaches change as a pest is introduced and becomes widespread.



Management approach options

There four broad weed management categories: prevention, eradication, containment and asset-based protection. The diagram in figure 1 illustrates how these categories relate to the invasion curve that shows the change in distribution of a weed over time. It's important to have a clear understanding of what the different terms mean, as they are often used incorrectly.

In figure 1, the longer a pest is present (horizontal axis) the more area it occupies (vertical axis) and management (coloured boxes) changes from prevention – when the pest is absent – through to impact mitigation – when the pest is widespread and abundant throughout its potential range. This can take many decades or just a few seasons, depending on the plant's lifecycle and other factors such as whether the plant is being spread or controlled by people.

The economic benefit is greater when weeds are prevented from entering a landscape or removed when only in small numbers.

When managing various weeds in 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 depends on the circumstances, including the current stage of invasion. In the early stages, we are attacking the weed to eradicate or contain it; in the later stages, we have accepted its presence and are protecting assets against impacts of the weed.

Prevention

If a weed is being considered for eradication, it is obviously beyond the prevention stage. However, observing weeds that are present, and knowing about land use and plants growing in surrounding areas, can help prevention in future. Investing in good hygiene practices for vehicles, equipment, people and materials being brought into areas is the most effective method of prevention (see resource 5 for weed hygiene notes).

Eradication

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

The longevity of viable seeds (or other propagules) indicates the length of the eradication response. The weed's seedbank and budbank have to be completely exhausted to ensure no new plants grow and reproduce. If the weed does reproduce, the 'response clock' has to go back to zero and counting must start again.

Containment

Containment is the prevention or reduction of the spread of an invasive species, e.g. by preventing invasions into new areas and eradicating any species found outside a defined area or beyond a defined line (Panetta 2016).

Containment is commonly advocated as the fall-back plan to eradication, but it is not necessarily any easier. 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. In either case, it should be noted that when containment is the aim, there is no end point to management. The weed has not been eradicated, so control is required to prevent further spread.

Further, if the weed can be easily spread by human (on clothing, via vehicles and equipment) or natural means (wildlife, livestock, wind, water), it will be harder to contain.

Protect agricultural and biodiversity assets (impact mitigation, asset-based approach)

In this approach, multiple weed management strategies are employed, based on the value of the assets. This approach relies on a good understanding of the at-risk asset(s), so you may need to seek advice from local biodiversity managers or Landscape officers.

1 SEARCH AND DETECT

This chapter guides users through the process of searching for and detecting weeds in the early stage of invasion. The suggestions, steps and scenarios can generally be applied across all land tenures and situations. Read on to learn more about:

- identifying target species and weed spread pathways
- looking for weeds opportunistically, e.g. during the completion of routine tasks
- more structured approaches to searching.

The information in this chapter can also be used when undertaking a delimitation survey (determining the full extent of the weed infestation) as part of an eradication response – see chapter 6 for more details.

Why search for new weeds?

‘Searching’ is the act of looking for something and ‘detection’ is the finding of something.

Focusing on widespread and well-established weeds is a common management approach. Depending on where you are in the state, you may be familiar with species like bridal creeper (*Asparagus asparagoides*), feral olives (*Olea europaea*), wild oats (*Avena* spp.), silverleaf nightshade (*Solanum elaeagnifolium*) or caltrop (*Tribulus terrestris*) and their impacts on biodiversity or production values.

Management of these well-established species is long-term, resource-intensive and time-consuming, which is why it is important to prevent new weeds from becoming established. Early detection of weeds that are new to an area, occur at low density and have limited distribution is the best way to prevent wide-scale establishment. The tools and strategies in this chapter show it is possible to be on the lookout for new weed threats, while continuing to address other management priorities.

Search types

Searching can occur in the field or away from the field e.g. in the office, also called a ‘desk-top’ search. It is typically characterised as one of two types – ‘passive’ or ‘active’. Opportunistic searching refers to incidental observation, where searching is not planned or carried out deliberately, but a weed is detected while another, unrelated activity is conducted.

Active or structured searching involves a deliberate effort to find something. The advantages and disadvantages of both search types are discussed below (tables 1 and 2).

Opportunistic (passive) search

Description: Casual, chance observations which usually occur during day-to-day activities. Also known as incidental or ad-hoc detection.

Examples:

- driving through your property/reserve/local area and unexpectedly spotting a new plant you have not noticed before
- inspecting the condition of some infrastructure and finding an unusual plant
- talking to a neighbour who shows you an old weed infestation you were not aware of
- finding a record of an unfamiliar weed on an old map in the office and keeping an eye out for it in the field
- inspecting feed lot areas on your property where you bring in fodder from off the property (figure 2).

Table 1 – Advantages and disadvantages of opportunistic searching

Advantages	*Disadvantages*
Economical because the detection occurs during other activities	Ad hoc and not strategic. Not targeted to specific species, pathways or high-risk areas
Anyone can do it, but most people who search for weeds opportunistically are very familiar with a particular area and the plants present in that area	Unlikely to provide a reliable measure of distribution unless the distribution is very restricted and obvious
Data quality can be more reliable due to local knowledge and experience	Usually limited to highly accessible areas such as roadsides, so many areas can go unsearched
A way of involving the local community in natural resource management	To be detected by chance, there is a high likelihood that the weed has already reached a sizable population that may be beyond eradication
	There is often a delay between noticing the weed and reporting it, meaning that the infestation could have spread
	Absence data is rarely collected

What is 'absence data'?

A formal record of a weed not being present in a search area. A weed should only be recorded as absent if a formal, structured search has been conducted, otherwise the area should be mapped as unsearched.

Structured (active) search

Description: A deliberate and systematic search for a weed within a defined area (Harris et al. 2001). This approach is usually targeted at a particular species or a group of weeds likely to occur within a geographic location and consists of a formal, repeatable method. The search may be conducted in the field or when looking through information about the area. Also known as strategic, formal or targeted searches.

Examples:

- searching a defined area around all boundary gates, carparks and entry points to a reserve or property
- searching and logging the route taken along pathways of weed movement e.g. along walking tracks, roads, watercourses etc.
- walking transect or grid lines in a paddock
- using remote sensing
- looking through plant databases for recorded weeds in a geographic area.

Table 2 – Advantages and disadvantages of structured searching

Advantages	*Disadvantages*
Greater chance of detecting species in the early stages of invasion, meaning that eradication is more achievable	More expensive than opportunistic searching
More thorough and considered	Resource and time intensive
Absence data is often recorded and acknowledged as being as useful as presence data	May require experienced and/ or specialised personnel

Figure 2 – feedlot areas are good sites to keep a look out for emerging weed threats.

Feed lot areas are important sites to monitor for weeds that may have been introduced with fodder.
Photo: Laura Williams, Department of Primary Industries and Regions

Planning a structured search

A structured search requires planning in order to maximise the likelihood of detection should a high-risk weed occur within the search area. This section lists 10 steps that can help in planning and conducting a structured search.

10-step guide to planning and performing a structured search

If you are planning a structured search from scratch, follow the steps in their logical order. The aim is to design the search to maximise the chances of success.

Step 1. Define the purpose of the search

There are a number of reasons for conducting a weed search. Knowing the reason for the search is a critical step in deciding what approach to take. Common reasons for weed searching include a desire to:

1. detect a weed in the early stage of invasion and suspected of being within your local area
2. detect weeds in the early stage of invasion that are not known to be present in your local area
3. develop a list of weeds present in your local area
4. demonstrate the apparent absence of a weed or suite of weeds from your local area.

This handbook is primarily concerned with the detection and response to infestations of weeds at the early stage of invasion (reasons 1 and 2 above). However, it is also important to be aware of all weeds that are present in the landscape or believed to be absent. This information allows you to manage any weed threats to your management area.

TIP: Write down the purpose of your search. Referring back to it during planning will help ensure the approach, scope and method you choose meet your needs.

Figure 3 – Determining the focus of a weed search. Weed searches will typically be either weed or pathway focused.

Step 2. Determine the focus of the search

Typically, the search for weeds at the early stage of invasion will either have a weed focus or a pathway focus (see table 3). The best approach to take depends on your individual situation and the resources available and may include a combination of these approaches (figure 3).

Weed focus

When searching for weeds at the early stage of invasion, it makes sense to target those weeds that pose the most serious threat to the area you want to protect.

Weed focused searches are both cost effective and targeted, allowing you to concentrate on the most serious threat to your management area. Focusing on a single species (or a small number of species) maximises the likelihood of detection.

What do you need to know to conduct a search with a weed focus?

If you choose a weed focus, the most important, and often the most difficult, thing to decide is what weed to focus on. The target species should pose the most serious threat to the area you seek to protect. Critical information for the preparation of a species focused search includes:

- name(s) of the focus weed(s)
- the weed's importance (weed risk) – see chapter 3 for more details
- identification features of the weed(s)
- likely pathways of entry, spread and potential land type/habitat to be affected
- life cycle of the weed(s) and the most appropriate time to conduct a search.

Resource 1 outlines some information sources and tools to assist in determining what weed could be focused on, along with existing priorities that can help narrow the search.

Pathway focus

There is often more than one serious weed threat to your area of interest. The time spent searching for one weed might be long enough for another weed to enter unnoticed and become established.

In this situation, it is often beneficial to focus the search effort on pathways of introduction and spread (see examples in figure 4) that are common to a suite of weed species, rather than focusing on a specific weed. Even if the focus is on one weed, considering spread pathways will maximise the likelihood of detecting the target weed. It also enables the observer to be open-minded and potentially notice other high-risk weeds that are not the target of the search.

Table 4 identifies some common pathways. A full list of potential weed spread pathways is included in resource 3.

Table 3 – Types of search focus

Weed focus	*Pathway focus*
When considering a single species or a small number of species that pose the most serious threat to the area you want to protect/manage	When more than one weed species of concern is affecting, or may affect, the area you want to protect

Table 4 – Accidental and natural pathways for weed spread in Australia, adapted from Sindel et al. 2008.

Pathway type	*Pathway vector*	*Examples*
Accidental spread by humans	Human apparel and equipment	Attachment of seeds and plant parts to clothes and footwear
	Machinery and vehicles	Attachment of seeds and plant parts to passenger vehicles, slashers, farm equipment, boats and earth-moving equipment
	Construction and landscaping materials	Contamination of gravel, soil, sand, mulch and turf
	Agricultural produce	Contamination of hay, grain and pasture seed
	Research sites	Escape from research sites
	Livestock movement	Through faeces or attached to livestock such as sheep, cattle, horses and goats
	Waste disposal	Unsafe dumping of garden refuse and aquarium plants
Natural spread	Birds	Through consumption and excretion of seeds and fruits or attachment of plant parts
	Other animals	Through consumption and excretion of seeds and fruits, and external attachment to native and introduced wildlife
	Wind	Distribution of wind-blown seeds and plant parts
	Water	Distribution of seeds or plant parts via waterways

If you choose to take a pathway approach, be mindful that greater planning is required, meaning more resources may be needed. Consideration still needs to be given to specific categories of weeds that might be found, otherwise the search may be too broad and not detect anything.

An understanding of spread pathways will assist in the selection of appropriate search techniques and can help in deciding what to look for and where.

Figure 4 uses a hypothetical nature reserve to illustrate some of the common accidental and natural pathways of weed spread into a reserve. Linear areas such as road, rail, and service easements provide a corridor for movement of plant propagules, either on their own or via vehicles or machinery. Likewise, waterways allow movement of some plant propagules.

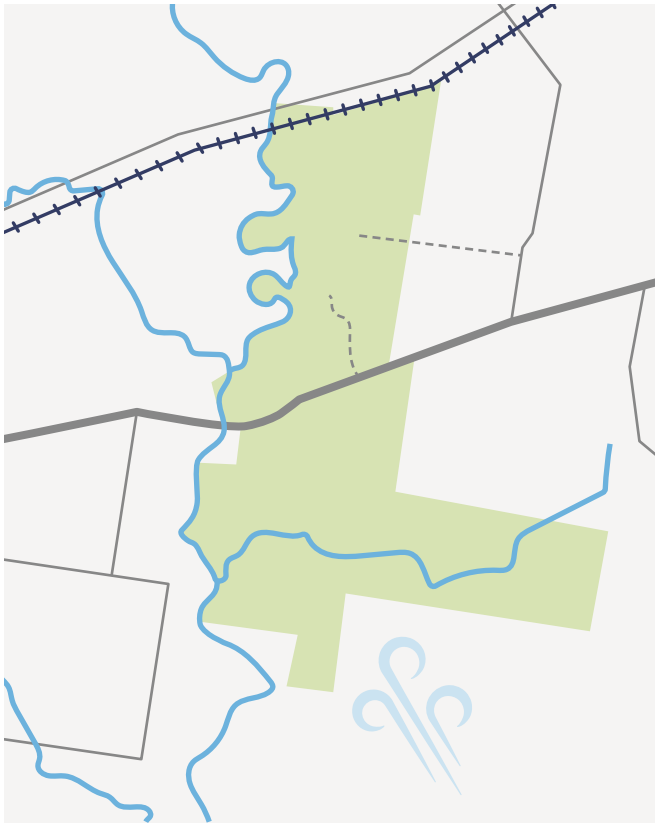


Figure 4 – Examples of common weed spread pathways that can be the target of pathway-focused weed searches.

Image: Matt Sheehan, Wild Matters

Other pathways that are harder to predict include wind dispersal or dispersal by animals such as birds, foxes and kangaroos. Knowing the dominant wind directions or the habitats utilised by animals that may spread weeds can help with the prediction of sites at higher risk of weed invasion from these pathways.

Regardless of the focus, your search will be more strategic, maximising the likelihood of weed detection if you consider spread pathways when planning and conducting your search.

Step 3. Timing the search

When to search

Some plants are only detectable when in flower, seed or fruit or in some other distinctive growth stage. Others become dormant and die back at certain times of the year. Therefore, the timing of a structured search needs to consider the life cycle of the target weeds. Even pathway-focused searches require consideration of the types of plants that may be encountered, so the most appropriate time to conduct a search can be chosen. There will also be logistical constraints to timing.

When planning the timing of the search consider the:

- time of year when the weed is most visible
- length of time that a weed will stay in a state where it is visible and identifiable
- weather conditions or events that may influence the weed's life cycle, survival, detectability or site access
- availability of resources (i.e. staff, vehicles, equipment etc.)
- timing of other management activities that may reduce detectability (i.e. planned burning or harvest activities etc.)
- seasonal growth of surrounding plants, including look-alike plants
- the time of year most risky for spreading a weed e.g. when a plant is shedding seeds that readily adhere to clothing or machinery.

Frequency of survey

It is necessary to search more than once to detect a weed. Ideally, search intervals (i.e. times between subsequent searches) are frequent enough to ensure weeds are detected while the infestation is still small enough to treat and before the weed has a chance to reproduce. Refer to resource 4 for a search frequency guide. The rate at which a weed establishes and spreads, and the detectability of a weed at a new site, are both a function of several factors (table 5).

Table 5 – Examples of factors that influence the rate at which a weed can establish and spread and/or how easy it is to detect the weed

Factor	Example
The weed's inherent biological capacity for growth and spread	Some plants produce high numbers of seeds or reach sexual maturity quickly
Habitat type the weed is invading	Thick bushland may make it harder to detect a new weed
Degree of disturbance at the site(s)	Many weeds require disturbance to establish, so a highly disturbed site may be more at risk to weed invasion
The weed's growth form	Larger plants, like trees and shrubs, are easier to detect than low-growing herbs or grasses

Step 4. Identify search areas within your site

Identifying search areas within your site is simply a way of focusing your search efforts. First consider the **land parcel** on which you are focused (figure 5). This may be a conservation park, a forestry block, a single farm or a cluster of adjoining properties within the same catchment. The **site** is the area of interest for the search and may be defined by considerations such as vegetation community or land type most susceptible to invasion. Sites can also be defined by logistical or geographical considerations or constraints, such as roads or river boundaries that divide the land parcel into more manageable areas.

The **search area** is the specific area(s) within the site that is the focus of the search. Again, these may be vegetation communities or high-risk locations such as roadsides. Finally, the **targeted survey area** is an area within the search area that is intensively surveyed. Note that this level of surveying may not be necessary or possible for the initial detection survey. It is more relevant to delimiting surveys and is therefore discussed in detail in chapter 6.

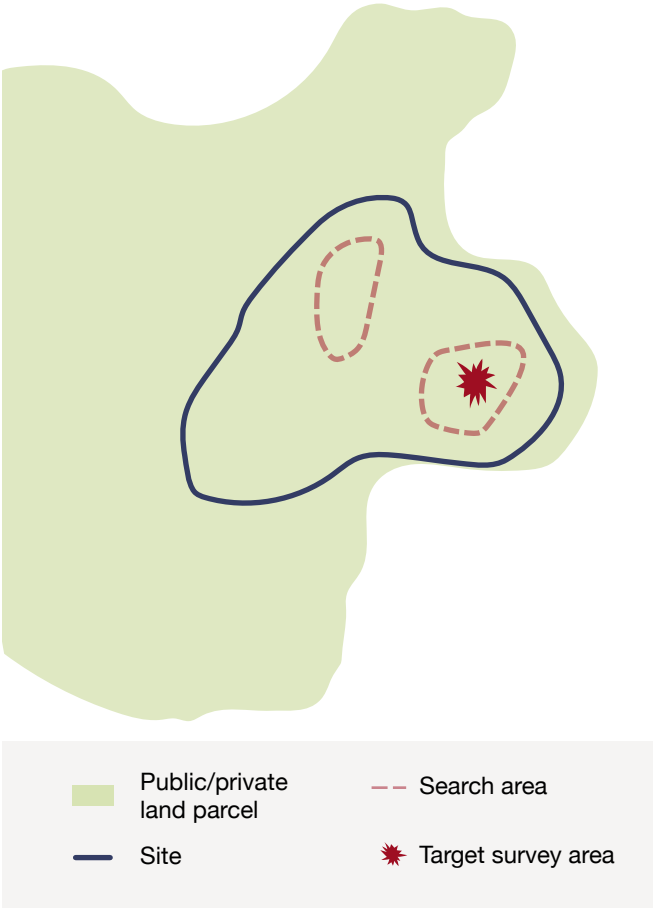


Figure 5 – An illustration of the different scales of site and the terminology assigned to them – the concept of land parcel, site, search area and targeted survey area.

Image: Kate Blood and Bec James, DELWP Victoria

A logical approach to selecting search areas for weeds at the early stage of invasion is to target sites where new species are most likely to arrive and establish, thereby biasing site selection in favour of finding the species. This targeted method is often the most reliable and time efficient. For an example of how to target a site search, refer to figure 6.

How to locate search sites to target

Digital or paper maps can be used to overlay various geographical areas of interest when identifying search sites. This can include:

- pathways (refer resource 3)
- priority conservation sites for protection
- sites at high risk of weed invasion
- weed hot spots near and within your site
- potential habitat for target weeds.

Also consider:

- existing weed distribution data, climate models and other sources to identify preferred habitat
- expert opinion in identifying locations at greatest threat from invasion
- key biodiversity or agricultural assets you want to protect from weeds (e.g. threatened plant species, pastures, watercourses etc.)
- logistical constraints
- practicality.

The hypothetical conservation area in figure 6 shows pathways and other points of interest that may help in both identifying the risks to the reserve and in targeting sites where searching could occur. High-risk areas within the reserve include spread pathways such as roads, railway lines and watercourses that traverse it. Other high-risk points could include picnic areas, parking areas, camping grounds and other amenities such as walking tracks or maintenance sites. There may also be sites within the reserve where illegal disposal of garden waste occurs, presenting a serious weed risk.

It can also be useful to establish a buffer or watch zone around the reserve. This may be a 5, 10 or 20 km radius in which threats or high-risk sites and their relationship to spread pathways is determined. In this example, the presence of a new weed has been identified along two direct pathways to the reserve. There is also a gravel quarry used for road construction located within the watch zone. These sites can also be hot spots for the establishment and spread of new weeds.

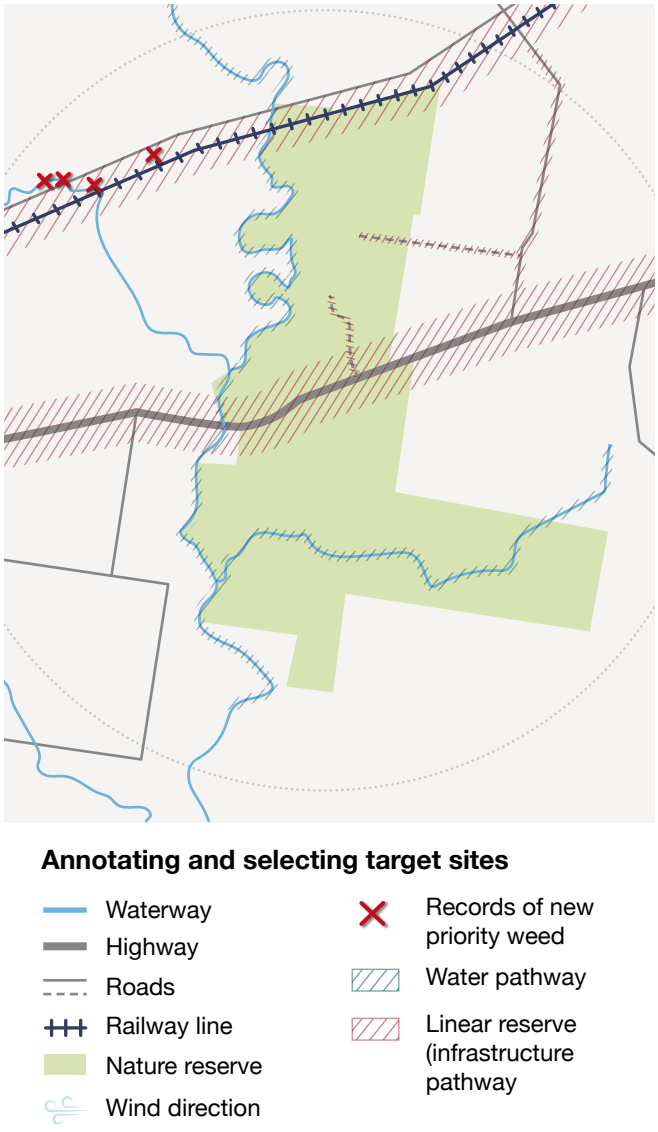


Figure 6 – Example of how to annotate a map to assist with selecting targeted sites.

Image: Matt Sheehan, Wild Matters

Step 5. Select a search technique

This section focuses on some of the most common search techniques to maximise the likelihood of detection.

When choosing a search technique, consider the following questions:

- What is practical? How many sampling sites can be surveyed taking into account the number of people and their expertise, time, cost, weather or other factors?
- What are the likely pathways of introduction? Consider how weeds may enter the search area and therefore where they are most likely to appear first.
- Are there any constraints? Does the size, terrain or accessibility of the site preclude a particular search technique? Is there a high risk that one or more methods of searching may spread the weed further?

TIP: Always document the search method so that future efforts can be repeated, and results compared.

There are some useful publications in the 'Further reading' section of this handbook.

Vehicle-based search

Vehicle-based surveys (figure 7) are particularly useful when searching linear reserves such as roadsides. The effectiveness of vehicle-based searches is influenced by a number of factors, including:

- width of the search area
- vegetation type and how conspicuous the weed is
- the number of species you are searching for
- terrain
- speed of travel
- traffic level and type
- weather and light conditions.

As mentioned in Step 3, timing also influences search effectiveness. Undertaking a routine trip at a different time of year may result in new weed discoveries.

Before you search:

- if possible, go to an area with a known infestation to get accustomed to the weed in the habitat to be searched
- plan the search route before starting
- familiarise yourself with look-alike species that occur along the search route.

Figure 7 – Select an appropriate search method. A vehicle-based search is particularly useful when searching linear reserves. It is important to follow safety protocols when undertaking a search of any kind.

Photo: Shannon Robertson, Department of Primary Industries and Regions

Suggested method

The suggested method for a vehicle-based search (see figure 8) is described here:

- vehicle-based surveys require two people – driver and observer/recorder
- travel between 5 and 40 km per hour, depending on vegetation type and road conditions
- Scan back and forth at right angles to the road. Keep line of sight level with the front of the vehicle. Do not look straight out the side window, as the vegetation appears to move faster at this point.
- Be mindful of hot spots along the route where extra attention may be required e.g. culverts and cuttings, water diversion channels, rest areas, road works storage areas, disturbed sites etc. Prepare to slow down for these hot spots.
- if unsure, the observer should get out of the vehicle and have a closer look if safe to do so
- Do you know the plant?
    - » **YES** – record location with a Global Positioning System (GPS) (point data or line), using template 2 to record other information.
    - » **NO** – record location with GPS (point data or line). Refer to chapter 2 for information on photographing and collecting weed specimens.

Safety

- Notify appropriate authorities (Local Council or The Department for Infrastructure and Transport (DIT)) of your intended search method, including safety/visibility equipment and procedures. Adhere to any additional requirements or modify your procedures to meet their requirements.
- Use hazard lights (where appropriate), headlights or a flashing beacon mounted on the vehicle. Also consider using 'vehicle frequently stopping' or 'slow moving vehicle' signs.
- Use appropriate roadwork signage on the roadside. Check requirements of the road manager. As a guide, place signs at intervals no greater than 2 km, at major intersections and along the road you are working on.
- Wear a high visibility vest.

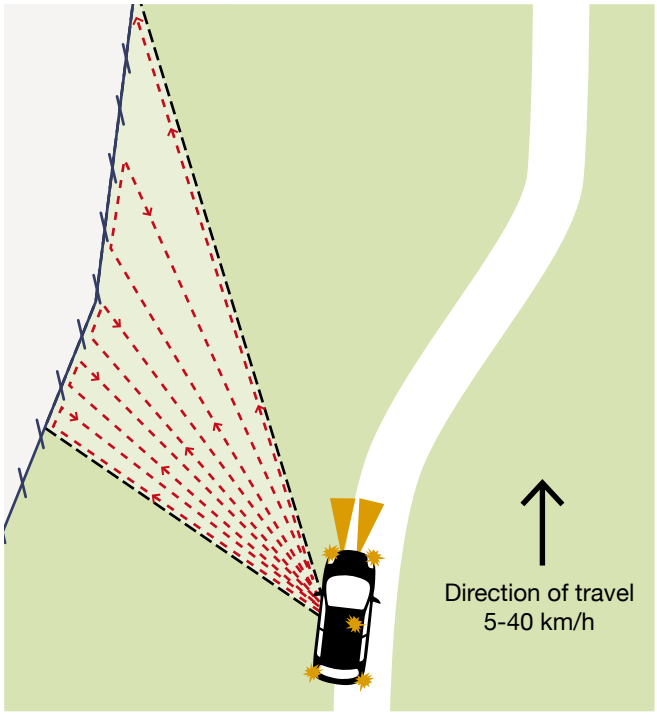


Figure 8 – Sketch of a vehicle-based search.

Image: Matt Sheehan, Wild Matters

Foot-based search

Searches by foot, while slower, allow you to search at high intensity, maximising the likelihood of detecting if a weed is present. This technique is effective in a range of habitats and for weeds of any growth form. It is useful for linear reserves, tracks or property boundaries where vehicle access is limited, as well as larger areas such as target area searches (refer to example in Step 4). It is often the technique most suitable for searches in remote areas, sensitive sites or dense vegetation.

Suggested method

Foot searches need to be structured and systematic to ensure all areas are covered. The easiest way to do this is to walk transects (straight lines) and continuously search along the transect line and on either side. The use of flagging tape, other markers, referencing landmarks or a GPS app can help to ensure you maintain a straight line. If the search area is a linear feature such as a track, creek or boundary fence, use that feature as the transect line (figure 9). If it is an area search, set up a series of transects parallel to each other across the search area.

Transect spacing

Spacing will depend on vegetation type, the overall size of the search area and the visibility of the target weed within the vegetation. If you are searching for a tree or shrub in large open grasslands, transects 50–100 m apart might be appropriate. However, most habitats require closer spacing. A good spacing for most vegetation types and weed growth forms is 5–10 m.

Transect alignment

In some circumstances, the direction or alignment of the transects should be considered, as they may help or hinder the search effort. For example, going across a slope rather than up and down may prove physically easier for the observers/recorders as well as provide better visibility. Sun glare in the eyes of the observer could make detection more difficult or a weed may become more visible with back lighting. Testing visibility with the sun either behind you or the target plant may influence the direction you walk.

Safety

- Snakes are a major risk to people conducting a foot-based search, particularly in grasslands. Wear long trousers, gaiters, and boots and carry appropriate first aid and communication equipment.
- be aware of past land uses and potential hazards such as traps, old fences, mine shafts etc
- it is both for safety and for practicality that at least two observers/recorders should conduct a foot search, walking adjacent transects.

Other important safety and hygiene information can be found in resource 5.

Figure 9 - Foot based search

Foot based search targeting Texas needlegrass Nassella leucotricha. Photo: Deb Lang Limestone Coast Landscape Board

Other types of search

Aerial (desk-top) search

Sometimes effective searching does not require you to go into the field. Aerial-based desk-top searches involve the analysis of vegetation from aerial images, either photographs or remote sensing data. These methods are useful when there is a clear distinction between the target weed and the surrounding vegetation, either with the naked eye, as shown on aerial photographs, or the difference in the absorption of light between different plant species, as shown through remote sensing imagery.

> Note that we are concentrating on weeds at the early stage of invasion, and therefore, depending on growth form and species distinctiveness or uniqueness, target weeds may not occur at densities that can be detected by such a method.

Aerial (field) search

It is possible to search from the air in person, such as from a helicopter or via remote camera such as a drone (unmanned aerial vehicles (UAV)). There are many laws that govern this practice and the costs may be prohibitive, but this may be an option depending on the circumstances.

Detector dogs

Detector dogs have long been used to detect biosecurity risks at quarantine facilities around Australia. Dogs can also be trained to detect a wide range of weeds occurring at low densities, which is perfect for weeds at the early stage of invasion.

Dogs are currently a major component of the hawkweed (*Hieracium* species) eradication programs in Victoria and New South Wales, and have been used to search for branched broomrape in South Australia. These dogs are fitted with GPS devices, which allow mapping of where searching has been carried out. This approach, when combined with traditional ground surveys and UAV surveys, has been a game changer in rapid response by increasing the area that can covered, reducing the time it takes and increasing the detection of weeds.

Figure 10 – Fudge the detector dog did a great job searching for branched broomrape in the Murray Bridge area.

Step 6. Data collection, capture and storage

Once a suspect plant has been detected, it is important to consider the following:

- what to record
- what data recording method to use (e.g. paper form, mobile devices)
- where data will be stored
- how the information will be shared.

A useful phrase to remember, particularly for opportunistic detections, is 'spot, stop and take a shot'.

What to record

At the initial search stage, the aim is to determine the suspect plant's identity and to confirm (or otherwise) the detection of a new species (refer to chapter 2 for more information). Therefore, the most important information to record is **where it is** so it can be located again either for further verification or to conduct a more comprehensive delimiting survey. In the case of weed focused searching, it is equally important to record **where it is not** i.e. where it is absent.

GPS coordinates are the most accurate way to record this information, either as:

- a point location or series of point locations (defined by a pair of coordinates)
- a polygon representing an area
- a linear feature (e.g. roadside), defined by start and end coordinates.

Site photos and references to landmarks are also useful. Further information, such as impact assessment data and treatment measures, can be collected at a later stage when assessing the weed's risk (see chapter 3) or conducting the delimiting survey (see chapter 6).

Recording sheets are located in the following appendices:

- Template 3: Field recording template for a weed search
- Template 4: Field recording template for opportunistic sightings and herbarium specimens.

Why record absence data?

Absence data – i.e. locations searched where the weed was not observed – is just as useful as presence data.

It provides a record of effort expended on searching, helps in the planning of future searches, and is useful in quantifying the spread of an infestation over time. When recording absence data it is also important to record the confidence you have in the observation. Not detecting a weed does not mean that it is not there (MacKenzie 2002). A way to collect absence data is to use the tracking function on a GPS and record where you have been.

Options for data recording methods can be found in resource 7.

Step 7. Training and preparing the search team

Depending on the scope of the search, several people may need to be involved – either in the field as observers or drivers, or in the office providing logistical support, identification expertise or entering data.

Prior to the search:

- identify the roles and duties to be performed
- organise appropriate information and training for each role
- check for consistency in observation recording and identification skills of survey team members.

Those involved need adequate training in survey methods, plant identification, specimen collection, hygiene, safety and preparation (figure 11). It is important to assess if people in the team observe and record weeds in a similar way. Consider running workshops or pilot studies before going out in the field to improve identification skills and consistency between observers. You can also prepare field kits or reference material showing examples of the target weeds and look-alike species. These can be of great assistance in the field, especially if loaded on mobile devices. See resource 8 for an equipment checklist, and chapter 2 for information on plant identification.

Ask the team to also record and photograph (geotag) any plants they suspect might be weeds, for opportunistic detection.

Step 8. Obtain permits and access permission

During the early planning stages of a search, it is wise to check what permission or permits might be needed to access areas. For example:

- road reserves that are managed by local councils or DIT may require access permission or permits, or at least provide notification of the planned search
- You may want access to private land in the management area, in which case you will need to contact property owners for permission. If you need to contact multiple property owners/ land managers on a regular basis, a simple communication plan with names, contact details and information on the search plan may be useful.
- The collection and transport of plants, including specimens, declared under the *Landscape South Australia Act 2019* requires a permit. Movement permits are issued by the the Chief Executive of the Department of Environment and Water via via the Department of Primary Industries and Regions Invasive Species Unit, or your regional Landscape Board.

TIP: Always ensure that you take copies (including on mobile devices) of the relevant permits and permissions with you in the field.

Step 9. Perform the search

Conduct the search according to the steps outlined above. Some important reminders:

- Have you notified all the relevant people and authorities?
- Is your job safety plan in place for reporting your movements in the field?
- Have you got good weed identification information?

Resource 8 contains a checklist of basic field equipment that may be useful to adapt for your purposes. Once you have refined your own list, it is easy to print a sheet for each field trip and check off equipment as it is packed.

Step 10. Store and analyse the search data

Make the most of the data collected so you and others can use it in the future:

- use the information in chapter 2 to verify plant identity and follow the steps to notify relevant people
- Interpret or analyse the data and link back to the original purpose of the search in Step 1. Use the results to demonstrate both the presence and absence of the target species within the survey area (e.g. make a map).

Figure 11 – Up-skilling in weed ID in preparation for a search for Coolatai grass (Hyparrhenia hirta).

2 NAME AND NOTIFY

This chapter helps with identifying and reporting weeds at the early stage of invasion, such as in figure 12. Read on to learn more about:

- what to do when you detect a suspect plant
- how to confirm the plant's identity
- who to notify about the plant's presence.

Recording weeds: spot, stop and take a shot

Once a weed is located, it is important to quickly and accurately record its details, particularly at the early stage of invasion – as it allows the source, extent and spread to be determined.

If the identity of the plant is unknown, it is important to record the location and date, so it can be found again. Taking a number of photographs can help with identifying and locating the plant again.

Figure 12 – A plant that is not familiar to you may turn out to be a weed at the early stage of invasion.

This is spiny rush, Juncus acutus. It might be taken for a native rush, until you notice the needle-sharp leaf tips and the larger seed capsules. Photo: Troy Bowman, Department of Primary Industries and Regions

Information to collect

Information can be recorded on one or two templates available at pir.sa.gov.au/weeds

- Template 3: Field recording template for weeds
  To be used when undertaking structured field searches (e.g. as per chapter 1)
- Template 4: Field recording template for opportunistic sightings and herbarium specimens.
  To be used when recording ad hoc or one-off sightings or when collecting specimens for the South Australian State Herbarium.

Images and video footage

Photos and videos can help with weed identification and for recording points in time to monitor change.

Bear in mind the purpose of the photo. If for identification, capture the important features that separate it from other species – close-ups of seed heads, flowers or leaves; if to document the infestation, longer shots showing the height, density and size of clumps are needed.

See resource 9 for a guide to taking photos and videos, including geotagging digital images.

What to record, where

Record-keeping systems should be accessible, simple to use and easy to share with others. Use existing systems if available or else create tables in Word or Excel to keep track of field observations, surveys and weed management activities.

Build routines around record keeping, including uploading details from notebooks and mobile devices to keep them up to date and accessible. Figure 13 identifies the two main steps involved in record keeping.

Mapping

There are a number of different reasons for mapping plants, including weeds. Weeds are mapped during the identification and reporting process, when delimiting an infestation (i.e. determining its boundaries), during treatment activities and when monitoring the success of treatments. Mapping the distribution and density of weeds also provides the foundations for weed management plans. It is important to know the location of weeds that may pose a risk to conservation areas, waterways, agriculture and infrastructure. There is no need to map every weed species that occurs at a site. Mapping small, new infestations of weeds also helps to prioritise which weeds to control and where.

A weed management map includes the distribution of weeds as well as other features that may impact planning. Mapping also helps to communicate outcomes to stakeholders and funding bodies. At a local level, and for the purposes of a landholder-conducted site assessment, it is not necessary to develop elaborate maps. The idea is to keep it as simple as possible, while producing a map or maps that are useful. Using GPS equipment (figure 14) greatly enhances the speed and accuracy of mapping.

More detail on the mapping is included in chapter 1 (Step 6. Data collection, capture and storage) and resource 7 (Methods for data recording).

A field manual for surveying and mapping nationally significant weeds (McNaught et al. 2008) provides detailed information of the process of mapping and basic mapping standards.

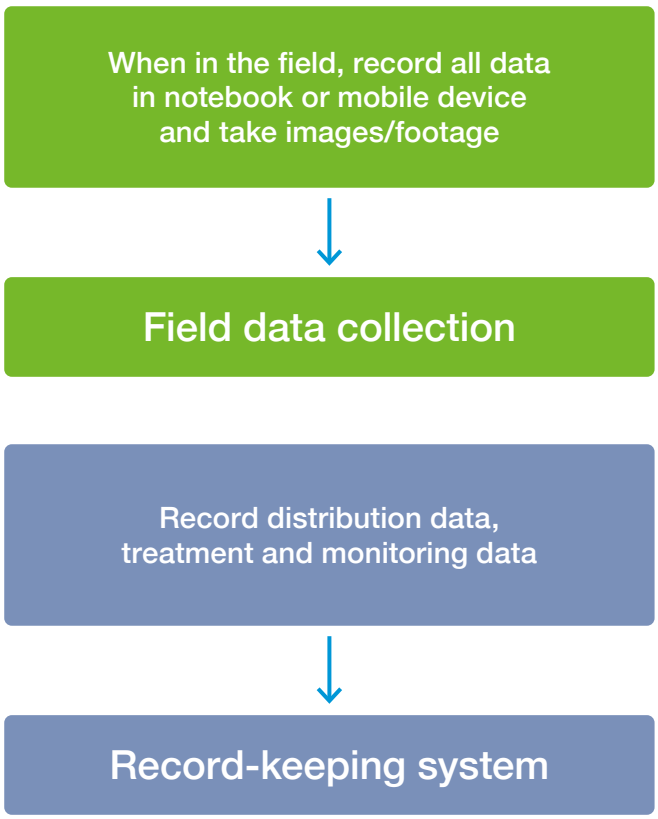


Figure 13 – Where to record data

Figure 14 – Record geographic information with a GPS or other device in the field.

Photo: Shannon Robertson, Department of Primary Industries and Regions

Naming weeds

While subtle, it is still important to clarify the differences between weed 'recognition' and weed 'identification'.

Weed recognition

Recognition is the ability to instantly recognise a plant, be able to tell whether it is a weed or indigenous, and possibly even be able to name it. It is the ability to know that a plant fits within the context in which you are viewing it. You may not be able to recall its full botanical name, even its common name, but you know that you have seen it before.

Over time, we build up an image library in our mind of the plants we have learnt to recognise. There are some that we remember from our grandmother's garden that we now see invading the local park, and some we have learnt through our work and training.

We see pictures of high-risk weeds, but we may never have seen them in the field. Even watching gardening programs on television or looking through gardening books and magazines helps to build up an image library in our mind.

Getting the 'gist' of a weed

As we become more familiar with a weed, we form a picture in our mind from all the times we've seen it – a general impression of its size and texture – its 'gist'. As we travel through the areas we are responsible for, we scan the vegetation. It is possible to scan vegetation at 100 km/hour as a passenger in a moving vehicle if we have the general 'gist' of familiar plants. It is when something we are not familiar with is spotted that we need to stop and have a closer look.

To be an effective land manager, it is important to become familiar with the plants, both native and introduced, in your area. Even if you cannot name them all, learn which ones belong and which ones are introduced. Your ability to recognise them will improve and you will become more familiar with what belongs and what doesn't.

Weed identification

Identifying an unknown plant accurately is an important step in determining whether it is in the early stage of invasion. Identification is the process of naming a plant through a more structured process than by instantly recognising it – either by using a botanical key or comparing it with a labelled herbarium specimen in a book or electronic source e.g. through the internet or mobile app.

Until a plant's identification has been verified through submitting a specimen (see the field recording template in template 4) to the South Australia State Herbarium, a proposed or preliminary name can only be called a 'provisional' identification.

Plants can be difficult to identify with certainty and misidentification is common. Take time to do it well and seek advice from others. There may be look-alikes that are easily confused, e.g. some native *Solanum* species with the weed *Solanum eleagnifolium* (figure 15) or native *Austrostipa* grass species with highly invasive *Nassella* grass species.

Always double check identifications you have assumed in the field.

There are many information sources to help with naming plants, either in the field or once back in the office. If further assistance is needed refer to table 6.

Figure 15 – lookalike plants

Some weeds like Solanum eleagnifolium (silverleaf nightshade, A) can be confused with similar looking natives such as Solanum esuriale (sometimes known as quena, B) and Solanum lithophilum (sometimes known as potato bush, C). The main distinguishing features are the shape of the anthers (yellow flower parts) and the colour of the fruits (berries). The fruits of silverleaf nightshade have distinct dark green stripes when immature, a feature lacking in most other Solanum species and the anthers of silverleaf nightshade are thin and the spines emerging from leaves are finer than most natives.

Table 6 – Sources of information for identifying weeds

Source of information	Examples and links
Contact experts	There are staff who can help in: • your regional Landscape Board • the Invasive Species Unit of the Department of Primary Industries and Regions • the State Herbarium, which has a specialist weeds botanist and other plant identification experts.
Look at pictures and read descriptions	See a range of information sources in resource 1.
Work through a botanical key	• there are many botanical keys in books such as *The Flora of South Australia* • other resources are available at the Electronic Flora of South Australia: flora.sa.gov.au/index.html • Lucid is an easy-to-use key.
Use networks and social media	• send pictures you have taken to others via email or post on a reputable social media site or forum requesting assistance • show people – e.g. colleagues or field naturalist – pictures that you have taken on your camera or mobile device • take people to the site where the plant grows (see hygiene notes in resource 5).
Access existing glossaries	Glossary of botanical terms

Verifying weed identification with specimens

Verifying the identification of a plant can be done by a person with a high level of skill and knowledge in plant identification such as the Weeds Botanist at the State Herbarium. Botanists usually refer to this formal process as 'determination'.

Before collecting plant specimens, seek advice from the Herbarium. Resource 10 provides more information. If you suspect the plant is a weed at the early stage of invasion, clearly label the package 'urgent, suspected weed, biosecurity risk'. This will ensure the package is handled correctly to avoid weed spread and allow prioritisation of specimen processing.

For more information on wellbeing, safety and hygiene when handling or collecting weeds for identification see resource 5.

Is it a 'new' weed?

Once you have verified the name of the weed, you can work out whether it is new to your patch, if it is new to South Australia and if it is declared under the *Landscape South Australia Act 2019*. There may be a legal requirement to do something about it. Your regional Landscape Board or the Invasive Species Unit in the Department of Primary Industries and Regions can help with further information.

Is it new to my patch?

Check local weed lists to see if the species has already been recorded. Local flora lists are available on the regional pages of the Landscape South Australia website. Local community groups, like Landcare and Friends of Parks may also keep lists of local plants.

Is it new to South Australia?

All the recorded native and naturalised plants in South Australia are listed in the census at flora.sa.gov.au/census.shtml, which is maintained by the State Herbarium (see table 6 above). If the weed has not previously been recorded in South Australia, you should report it to the Invasive Species Unit immediately.

What is its legal status?

To check if the weed is declared in South Australia under the *Landscape South Australia Act 2019*, go to the plant policies page at the Department of Primary Industries and Regions website. You will see the list of weeds declared in South Australia and the sections of the Act applying to them.

Correct weed names

The Department of Primary Industries and Regions uses the scientific names of weeds adopted by the State Herbarium, which align with names used in the *Australasian Virtual Herbarium*.

Figure 16 – Blue periwinkle (Vinca major)

Relatively easy to identify when it is flowering as there are not many look-alikes. Although widespread in high rainfall regions, it is still moving to new sites with dumping of garden waste. Photo: Deb Lang, Limestone Coast Landscape Board

Writing weed names

When writing weed and plant names, it is recommended that you use the standards used by the State Herbarium. Some basic tips on writing weed and plant names are included below and there are more detailed tips in resource 11. For more information, check out ***Plant names. A guide to botanical nomenclature*** (Spencer 2007) .

Common names

It is recommended that common names are spelled with lowercase letters except where they contain the name of a place or a person, for example:

Aleppo pine

cutleaf mignonette

Many weeds have more than one common name. This can be confusing when searching for information in books or on the internet. The same common name can be used for different weeds. It is always better to use botanical names whenever possible.

Botanical names

The two words that make up the species name (genus and specific epithet) are written in italics, and a species can sometimes be broken into smaller categories: subspecies, variety or form, or cultivar, for example:

Ferraria crispa

Fallopia japonica var*. compacta*

Acacia nilotica subsp*. indica*

Zantedeschia aethiopica 'Green Goddess'

The genus, e.g. ***Ferraria*** above, is spelled with a capital for its first letter; the specific epithet (sometimes simply called 'species') e.g. ***crispa*** above, is with lower case. See resource 11 for more tips on writing weed and plant names.

Learning the names of weeds

When you are starting out, learning names of weeds can be overwhelming – there are so many to learn. Don't be daunted – just start and keep going. Repetition, practice and persistence are key.

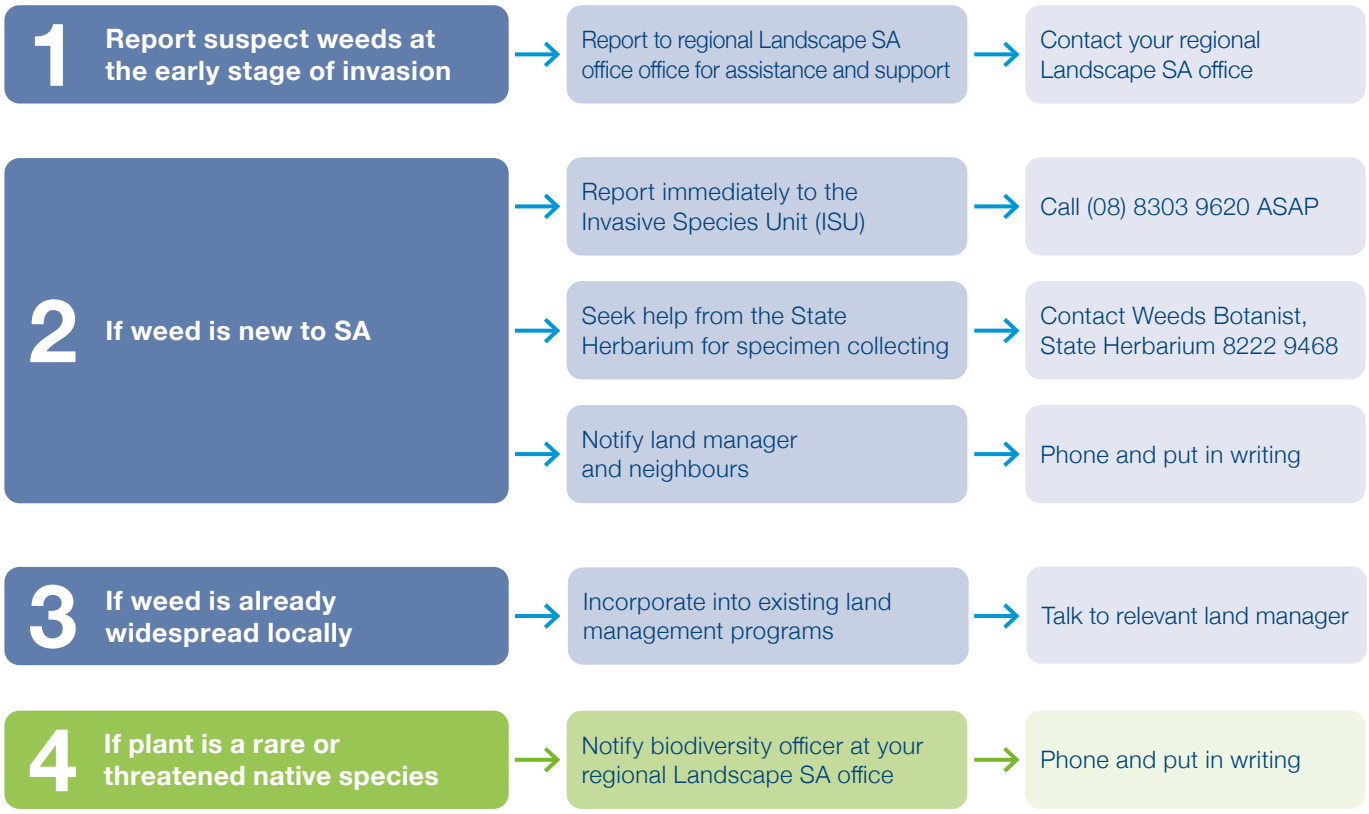
Here are some ideas:

- start with the ones you are familiar with, build your confidence and work from there
- regularly flick through weed and gardening books, newsletters, magazines, nursery catalogues and mobile phone applications, and look at the images and read the names
- put a weed poster in the tearoom or bathroom
- look through website image galleries and watch YouTube videos on weeds, or put weed images on your computer screen-saver or on an electronic digi-frame or tablet to scroll through repeatedly
- create a scrapbook or folders of articles and images (hard copy and/or electronic) or an electronic pin board e.g. on Pinterest
- collect a small specimen library (personal herbarium) of pressed specimens – a safer (see notes on hygiene in this guide) and easier-to-maintain alternative is scanned or photographed specimens kept in a folder to flick through
- go out into the field with other people, volunteers or botanists, and visit nurseries and botanic gardens where plants are labelled
- make a point of learning both the common names and botanical (scientific) name
- use word rhymes or other associations to help you remember the names e.g. *Arundo donax* sounds like *Arundo* 'gonads', *Nassella* has two s's and two l's – rehearse and repeat the name in your head
- compare confusing look-alikes to work out the finer details of telling them apart and commit to memory or keep a cheat-sheet on your mobile device
- A weed a week. Each week, try to learn a new weed. Have a document-stand on your desk and each week flip to another page in a field guide and leave it open – practise writing the name or doodle-draw features of the plant and summarise the main points about the weed.

Reporting and notifications

Once information is captured and recorded, the relevant information needs to be shared and passed on to others who may need to act further on it. Follow the guide in figure 17 below:

Figure 17 – Who to notify about weeds at early stage of invasion



3 ASSESS THE RISK

After confirming the identity of a weed, you can now determine the 'weed risk' that the plant poses, which in turn will help determine how it should be managed. Understanding risk is an important step towards determining an appropriate response. This chapter outlines the process of determining the risk of a weed suspected of being at the early stage of invasion. Read on to learn more about:

- what weed risk is
- how to find out the risk rating of a plant
- generate a risk rating using a rapid assessment tool.

What is weed risk?

The risk a weed poses is a measure of its (i) invasiveness (ability to spread and outcompete desirable vegetation), (ii) its impacts on environmental, agricultural or cultural/social values and (iii) the ability to find, access and control the weed. Weed risk also considers the weed's current and potential distribution, to determine how established the weed is and how much further it could spread.

Weed risk assessments and risk rating

Weed risk is predicted using a weed risk assessment (WRA). This is a structured series of questions that considers the probability that a plant will persist and spread (its invasiveness) and the consequences of such spread (its impact), to determine a risk rating. Risk ratings are useful to help work out which weeds pose the most serious threat. Ratings are often expressed as being very high, high, medium, low, or negligible. Many WRA tools used in Australia also assign management objectives (e.g. prevention, eradication, containment or asset protection) to the risk rating. Knowing a weed's risk is helpful in making standard, informed decisions on weed control priorities. Risk ratings can be used to:

- help determine which species are a high priority to search for
- indicate the risk posed by a weed at the early stage of invasion, compared to existing weeds on the site
- assist in deciding if the weed is a target for eradication when used in conjunction with delimitation (distribution) data.

South Australian ratings

All weeds declared under the *Landscape South Australia Act 2019* have been assessed using the South Australian Weed Risk Management System to determine their risk and the feasibility of managing them using available weed management options over the whole state. Existing South Australian risk ratings provide the most relevant rating for your situation. A list of high-risk species with the potential to become new and emerging weeds is provided in resource 2. However, this list is not exhaustive, as there are hundreds of plants that could have a detrimental impact on the environment or agriculture in South Australia which have not been assessed. A rapid, preliminary screen for weed risk for species not currently declared in South Australia is outlined in 'determining weed risk' (below).

Other sources of risk ratings

In addition to South Australia WRAs, there are risk ratings available for a range of weeds from other Australian states and territories. It is important to remember that a weed's risk rating is generated for a particular land use within a defined geographic area. This takes into account local climate and how much of the weed is already growing in that land use. Risk ratings from other parts of Australia should be used with some caution. They may be useful as a guide, helping you to decide if further risk assessment is warranted, but they should not be used to make management decisions.

Determining weed risk

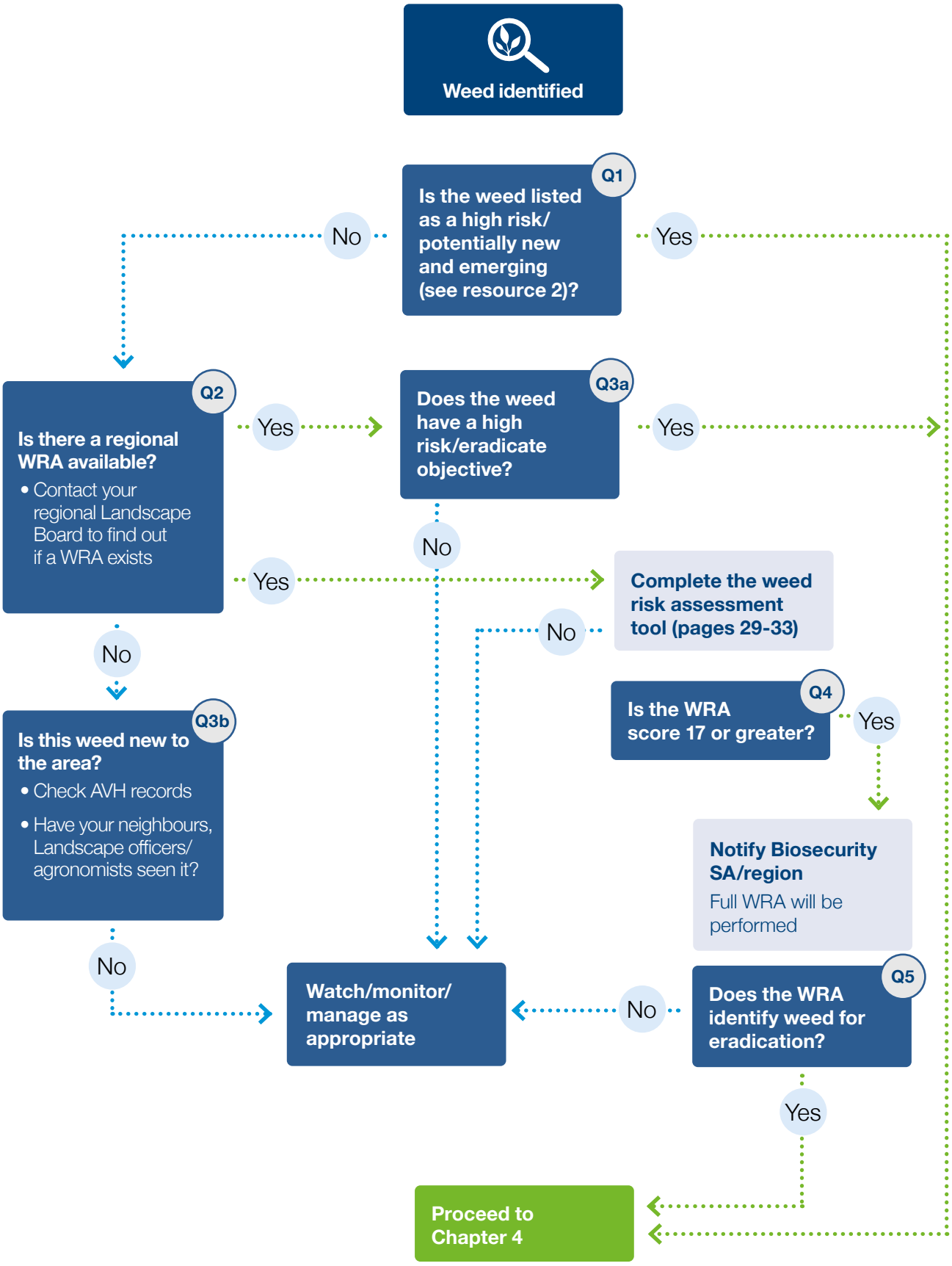
Figure 18 is a decision support tool to help in determining weed risk.

- **Question 1** of the tool asks: *'Is the weed already listed as high risk/potentially new and emerging?'* In other words, does it have a WRA completed for SA that shows it has high risk? To answer this question, refer to the list of species contained in resource 2. If it is listed, you can proceed to the next chapter of this handbook.
- If the weed is not listed in resource 2, proceed to the next blue box (**question 2**) down the left-hand side of the tool: '*Is there a regional WRA available?'* The weed may have been assessed at the regional level in which case you can use the results to guide your management decision.
- If there is a regional WRA, proceed to **question 3a**: *'Does the weed have a high risk/eradicate objective?'*
  - » If the answer is **yes** you can proceed to the next chapter of this handbook.
  - » If the answer is **no** it is recommended to watch/monitor/manage the weed as appropriate.
- If there is no regional WRA, proceed to **question 3b**: *'Is the weed new to the area?'* To answer this you may need to chat to neighbours, Landcare groups, weed experts or your local agronomist and ask specifically: *'Have you seen it? How long has it been here, how widespread is it?'* It will also pay to check herbarium records (see table 8 below). If the weed has been around for a while, it is unlikely to be in the early stage of invasion, and enough may be known about it to know the risk it poses and the best way to manage it.
  - » If the answer is **yes** it is recommended you complete a WRA and continue through the remaining questions in the decision support tool.
  - » If the answer is **no** it is assumed the weed is common or widespread and therefore not a weed at the early stage of invasion or an eradication target. The recommended action is to watch/monitor/manage the weed as appropriate.
- A WRA is recommended when a weed does not have an existing WRA result and is considered to be new to an area. The outcome of the WRA (**question 4**) will determine what to do next.
  - » If a weed has a score of less than 17, the recommended action is to watch/monitor/manage the weed as appropriate.
  - » If a weed has a score of 17 or above, it is recommended you notify the Invasive Species Unit of the Department of Primary Industries and Regions and your regional Landscape SA office. A full WRA will be performed.
- The final question is: *'Does the full WRA identify the weed for eradication?'* (**question 5**).
  - » If the answer is **no** the recommended action is to watch/monitor/manage the weed as appropriate.
  - » If the answer is **yes** you can proceed to the next chapter of this handbook.

If you arrived at the box titled 'Watch/monitor/manage as appropriate', this could mean one of the following outcomes:

- Based on a WRA, the weed may be too widespread to consider it for an eradication response.
- It may be a high-risk weed, but not high enough to warrant an eradication response. It may however still need to be managed to either contain its spread or reduce its impact on important assets (refer to the introduction for more information on management approaches.
- Based on a WRA, the weed is low risk. It may still pay to watch or monitor it periodically (e.g. once a year) to see if it is spreading or causing impacts, so that you can manage it if required.
- There was no WRA, but based on the evidence at hand, it was concluded that an eradication response was not required. We can sometimes make mistakes, new information may come to hand, or a plant may behave differently than we expect. So it is wise in this case to keep an eye on it for a few years. This may involve visiting the site once a year to see if it is spreading or to observe if it is having any impacts and acting appropriately if it is.

Figure 18 – Decision support tool to guide you through the process of finding a weed risk rating and the appropriate next steps



Assessing weed risk using the weed risk assessment (WRA) tool

The **weed risk assessment (WRA) tool** (below) is an easy-to-use preliminary assessment score sheet that allows you to rate the risk of a weed yourself, using your knowledge and perhaps a quick online search. Note that the WRA tool is not a substitute for a formal weed risk assessment, as the outcome will only tell you if a formal weed risk assessment should be performed or not. However, it is a useful exercise as it will give you the opportunity to learn more about the plant, an understanding that you will need if you do intend to manage it in future. It will also give you a good evidence base to present a case to the Department of Primary Industries and Regions or your regional Landscape South Australia office to ask for a full WRA to be completed.

The WRA will ask you a series of questions, which you score based on a scale of 1 to 4. If the weed score is 17 or above, the weed is high risk and further investigation is required. In this case contact the Invasive Species Unit or your regional Landscape South Australia office and ask for a formal WRA to be performed, based on your preliminary findings. If the formal WRA supports your findings (question 5 of the decision support tool), proceed to chapter 4 of this handbook.

Fill out the following scoresheet to generate a rapid risk score, which can be translated into a rating (see table 7). The questions are designed to be answered based on a combination of field observations, existing knowledge, advice from weed experts, research and available literature. Refer to table 8 for useful information sources that may help you to answer the questions.

IMPACTS

1. WEED HISTORY – What is the weed history of the plant? ☑		***Score***
☐ It is a weed elsewhere in SA.	**4**	
☐ It is a weed elsewhere in Australia.	**3**	
☐ It is a weed overseas.	**2**	
☐ It is not known to be weedy, but other forms of this plant and/or plants in the same genus are weeds in Australia and/or overseas.	**1**	
☐ The genus is not known to be weedy.	**0**	

2. COMPETITION – How well does the plant outcompete other types of plants? ☑		***Score:***
Select the vegetation size classes the weed could dominate: ☐ trees (or emergent aquatics) ☐ groundcovers (or submerged aquatics) ☐ shrubs (or surface aquatics).		NA
☐ If not controlled it could grow to dominate all three of the above size classes of plants.	**4**	
☐ If not controlled, it could grow to dominate one of the above size classes of plants **OR** at certain times of the year it can dominate two size classes.	**2**	
☐ If not controlled, it could dominate one of the above size classes at certain times of the year.	**1**	
☐ It is not competitive and is readily dominated by most other plants if they are not controlled.	**0**	
3. HEALTH – Is the plant a health risk to people and/or animals? ☑		***Score:***
☐ It is highly toxic and has caused deaths elsewhere.	**3**	
☐ It can cause significant physical injuries or illness.	**2**	
☐ It can cause slight physical injury or mild illness with no long-lasting effects.	**1**	
☐ It is not a health risk to animals or humans.	**0**	
4. MOVEMENT – If the plant escapes does it have the potential to block the movement of people, animals, vehicles or water? ☑		***Score:***
☐ A group of plants is very tall, thorny, tangled and/or dense & impenetrable year-long.	**3**	
☐ A group of plants is rarely impenetrable but does significantly slow physical movement year-long.	**2**	
☐ A group of plants is never impenetrable but can significantly slow movement for part of the year.	**1**	
☐ The plant has no significant effect on movement.	**0**	

5. ENVIRONMENTAL EFFECTS – Does the plant have attributes that, at high density, could cause detrimental changes to the environment? ☑		Score:
Select all of the following attributes applicable to the plant: ☐ highly flammable high water use ☐ brings salt to soil surface or fixes nitrogen ☐ removes habitat or food source for native animals ☐ provides food source for pest animals.		NA
☐ The plant has two or more of the above attributes:	**2**	
☐ It has one of the above attributes.	**1**	
☐ It has none of the above attributes.	**0**	

6. EASE OF CONTROL – How easy is the plant to kill? ☑		Score:
☐ Hard. It readily tolerates or reshoots after herbicide application, cutting, cultivation, grazing or fire.	**3**	
☐ Medium. One herbicide application or cultivation kills the plant, but not cutting, grazing or fire.	**2**	
☐ Simple. Plants are killed by herbicide, hand-pulling, cutting, grazing or fire.	**1**	

POTENTIAL DISTRIBUTION

7. HARDINESS – How well is the plant adapted to the local climate? ☑		Score:
☐ It is a weed of drier, exposed land in the region or in other parts of Australia or overseas with similar climate types.	**3**	
☐ It is a weed of wetter, sheltered land in the region or in other parts of Australia or overseas with similar climate types.	**2**	
☐ It has naturalised occasionally in the region in specialist habitats (i.e. it has a narrow ecological amplitude) but hasn't formed high-density infestations. It grows in distinctly different climates elsewhere in Australia or overseas. (*If known*)	**1**	
☐ The local climate is very different to where the plant grows elsewhere in the world and it has not been recorded as naturalised in the region or in other parts of Australia or overseas with similar climates.	**0**	

INVASIVENESS

8. REPRODUCTION – How well does the plant reproduce? ☑		***Score:***
Select all applicable plant attributes: ☐ visibly high seed production (leaving aside the question of percentage seed fertility) ☐ seedlings are commonly seen near mature plants ☐ mature plants visibly reproducing by vegetative means (suckers, stolons etc).		NA
☐ The plant has all three of the above attributes.	**4**	
☐ It has two of the above attributes.	**3**	
☐ It has one of the above attributes.	**2**	
☐ It has none of the above attributes but is able to reproduce by itself.	**1**	
☐ It sets no seed in any natural circumstances and has no vegetative spread. The plant can only be propagated with human assistance (e.g. shoot cuttings).	**0**	

9. NATURAL SPREAD – Are the plant's propagules (seed or vegetative) likely to spread long distances to susceptible habitats by natural means? ☑		***Score:***
Select all applicable dispersal mechanisms for the plant: ☐ birds ☐ water ☐ ground animals ☐ wind		NA
☐ Propagules are likely to be dispersed by at least three of the above mechanisms.	**4**	
☐ Propagules are likely to be dispersed by two of the above means.	**3**	
☐ Propagules are likely to be dispersed by one of the above means.	**2**	
☐ Propagules are not normally spread long distances from parent plants.	**1**	
☐ Propagules are not produced.	**0**	

10. HUMAN SPREAD – Are the plant's propagules (seed or vegetative) likely to spread long distances due to human activities? ☑		*Score:*
☐ The plant is appealing (attractive or with edible fruit) and easy to propagate.	**3**	
Select all applicable means by which propagules are likely (or known) to be dispersed: ☐ people/clothing/footwear ☐ vehicles/machinery ☐ contaminated soil.		NA
☐ Propagules are likely (or known) to be dispersed by two or more of the above means.	**2**	
☐ Propagules are likely (or known) to be dispersed by one of the above means.	**1**	
☐ Propagules are not normally spread long distances from a parent plant.	**0**	

Table 7 – Translating a score into a risk rating and the appropriate action required

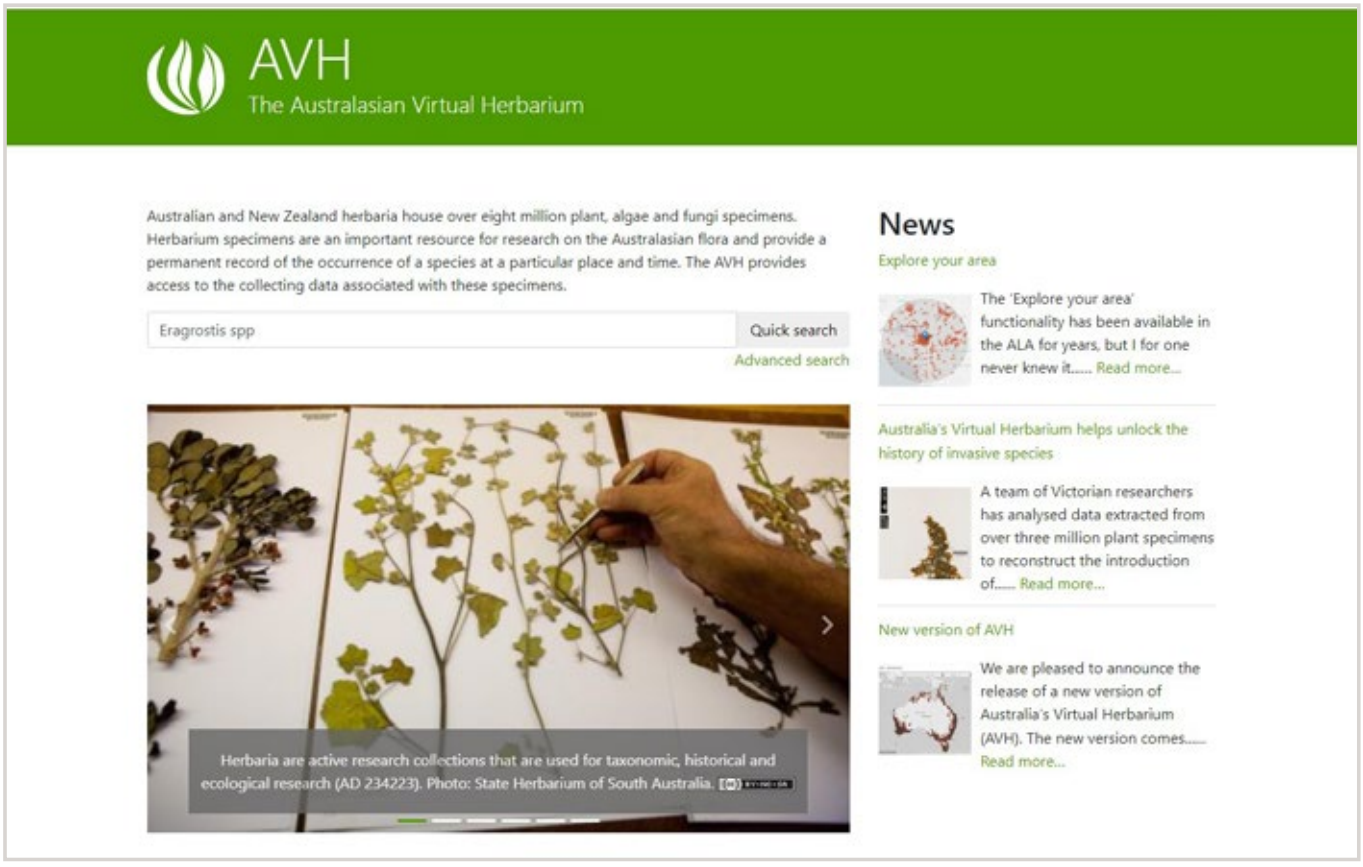
Score range	Risk rating	Action
2 – 9	Low weed risk	No action required
10 –16	Medium weed risk	Monitor weed. If the weed score is at the upper end of the range (16) consider seeking assistance to perform a formal WRA
17+	High weed risk	Seek assistance to perform a formal WRA

Table 8 – Useful information sources to refer to when using the WRA tool

Data sources	*Data description*	*Custodians or contacts*
Australasian Virtual Herbarium (AVH)	This website maps the recorded locations of plant specimens, including exotic species, held within Australia's national and state herbaria (figure 19).	avh.ala.org.au/
Atlas of Living Australia (ALA)	This website contains a collection of data for Natural History Collections for Australia, including plants. The Atlas maps these records and allows access to each data point. Images are available for some species.	ala.org.au/
California Invasive Plant Council	This website contains invasive plant inventory, definitions, impacts, completed risk assessments, information, research, distribution/risk maps and useful links.	cal-ipc.org/
Center for Aquatic and Invasive Plants, University of Florida	This website contains a plant directory that can be used to search for plants by scientific or common name. contains photos and information about the plants impacts.	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.	efloras.org/
A Global Compendium of Weeds	Used to determine in how many regions of the world the species of concern has been recorded as a weed (It is assumed that a formal identification of the plant of concern has already been made).	hear.org/gcw/
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.	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.	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.	cabi.org/isc/

Data sources	*Data description*	*Custodians or contacts*
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.	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.	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.	tropicos.org
Weeds Australia	This website has a useful list of weeds, including a National Environmental Alert List. It also has a weed identification tool.	environment.gov.au/biodiversity/invasive/weeds/

Figure 19 – The Australasian Virtual Herbarium (AVH) website is a good way to visualise a weeds distribution and can help determine if a weed is new to your area.



4 ERADICATION CONSIDERATION

This chapter will guide users through the process of determining if eradication is a suitable management response for a given situation. The suggestions, steps and scenarios can generally be applied across all land tenures and situations. Read on to learn more about:

- what eradication means and involves
- whether eradication is a realistic management option
- what contributes to a successful eradication response
- how to assess a weed's suitability for eradication.

What is eradication?

Eradication is the elimination of every single individual element (including propagules e.g. seeds and buds) of a species from a defined area in which recolonisation is unlikely to occur (Panetta 2016). Eradication typically refers to removal of all populations within a given geographical unit, usually a state or a country.

The *South Australian Weed Risk Management System* describes the aim of eradication as 'removing the weed species from the management area'. This includes the following guiding principles:

- detailed surveillance and mapping to locate all infestations
- destruction of all infestations including seedbanks
- preventing entry into, and movement and sale within the management area
- must-not-grow and all cultivated plants to be removed
- monitor progress towards eradication.

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
- 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).

Questions of scale

Whilst it is common to apply the term eradication to the state or even national scale, it's possible your focus will be on eradication of a weed at the local or property scale. Localised eradication is when populations of a weed are completely removed (e.g. from a property or catchment area), yet other populations exist elsewhere (e.g. another region of the state). It may be that the weed you are focusing on:

- is new to South Australia
- is not new to South Australia but is new to your region
- is not new to your region but is new to your area or property.

All of these scenarios represent eradication or localised eradication opportunities.

Why eradicate a weed?

There are many good reasons why eradication of invasive plants is worthwhile. Eradication has considerable benefits due to its potential to provide substantial and long-term ecological and economic benefits. Despite the benefits, eradication is often difficult to achieve and best applied to populations that are in the early stage of invasion and have limited distribution throughout the landscape. Careful selection of the target weed is important, as are the operational procedures used to achieve eradication.

Plants are not well represented on the list of eradication successes and can be difficult targets owing to problems with detection and persistent seedbanks. Generally, the success rate of weed eradication programs is low, at around 10-20%.

The intensity of effort and duration of effort required to achieve eradication is far greater than that required for ongoing control or management of invasive plants. Eradication of even relatively small infestations can take decades to achieve, particularly if propagules are long-lived and it is difficult to prevent reproduction.

By choosing eradication targets carefully using the earlier chapters in this handbook, the likelihood of success should increase considerably.

Making management decisions in the real world

By now you know the species you are dealing with, and you have an assessment of the level of risk associated with the weed and an outcome recommending eradication. It is now time to put a reality check on that assessment.

Think about the big picture and be brutally honest with your circumstances. The reality is that no matter how personally passionate you are about protecting production and biodiversity values, if you don't have the resources or support to act, trying to do so will most likely end in failure, and at worst, end in compromising job satisfaction and wellbeing.

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.

By starting eradication responses that are unlikely to succeed, the risk is 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 supported 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 managers need to be able to find your plan after you have moved on. Hopefully the weed's distribution hasn't increased too much by the time resources become available.

This document is focused on the initial decision concerning whether to attempt eradication, based on the information available at the time. As an eradication response proceeds, new information tends to emerge e.g. additional sites are found, treatments work better or worse than expected etc.

The management approach may change as a result and you may find that containment or asset protection is a more suitable option.

A decision to run an eradication response is subject to review (see chapter 6) and it is normal that some attempts will be halted after a short time – be prepared for this possibility.

Broader management considerations

Land management involves balancing many requirements – of which weeds are only one. Decisions about which weeds to manage have to be made in this broader context. It may be that you or your organisation have 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 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. Collaborating with adjoining land holders, community groups or governmental agencies dealing with the same weed or circumstance could be beneficial.

Embarking on eradication is complex and cannot be based solely on a weed risk assessment score. Other factors including estimated cost and length of time required to achieve 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 clear understanding of what you want to achieve and to know this goal is shared by the people you work with, as well as those with an interest in the area being managed.

Factors influencing eradication success

Generally, two groups of factors influence the eradication success of invasive plants. The first relates to site and species factors, which are beyond the control of a land manager, for example, the capacity of the target species to produce seeds or other propagules. Much of this information is considered in a formal weed risk assessment. The second group relates to organisational attributes, which can be influenced by management, for example, the allocation of sufficient resources to manage an eradication program.

Retrospective reviews have identified several important factors that influence the success of eradication programs, many of which occurred in Australia. This pool of knowledge is helpful for guiding the design of eradication programs and is summarised in table 9.

Table 9 – Summary of the factors influencing eradication success

Factor	Explanation
Time present	Infestations at the early stage of invasion are more feasible to eradicate than those that have been present for long periods.
Propagule longevity	The shorter the life span of propagules (seeds, bulbs, buds etc.) the more feasible to eradicate.
Time to sexual maturity	The longer the time to sexual maturity, the more feasible to eradicate.
Detectability	Comprised of: **Detection distance –** The longer the distance over which a species can be detected the more feasible to eradicate. **Detectability period –** The longer the species is detectable within its growth cycle, the more feasible to eradicate.
Previous eradication success	If the species has been eradicated elsewhere, the more likely it can be eradicated again.
Infestation size	The smaller the infestation, the more feasible to eradicate.
Delimitation	The greater the searching effort, the more feasible to eradicate.
Monitoring rate	The more frequently eradication efforts are monitored, the more feasible to eradicate.
Site accessibility	If a site is easy to reach, ideally via vehicle, it's more likely to be visited regularly, either for control or monitoring purposes.
Public perception	Species that have no conflicting perceptions within the public forum are more feasible to eradicate.

Time weed has been present

Biological invasions are often characterised by a lag phase followed by a rapid expansion in extent and density. Commencing eradication projects at the earliest possible stage in the invasion curve improves the chances of success. Therefore, knowing how long an invasive plant has been present at a site is important.

Understanding biological traits

The vulnerability of invasive plants to treatment methods and their ability to re-invade is strongly influenced by the biological traits of the target species, especially how quickly the species reproduces and for how long its propagules persist. Therefore, eradication programs require a good understanding of the target species' biology, in particular its dispersal ability, its reproductive biology and its life history. In some circumstances, when an emerging weed has been detected in a new environment, little information on its life history or biological attributes may be available, in which case, data from close relatives may have to be used.

Detectability of target species

The detectability of the target species – both the annual period of detectability and detection distance – has a positive influence on the time taken to eradicate a population. Detection distance – the distance from a plant at which it may be seen – has a large influence on the time to achieve eradication, which reflects the total search effort required to find all individual plants. Plants that are generally difficult to detect or are only detectable for a short period are more likely to escape control efforts.

Previous eradication success

Plants that have been eradicated elsewhere are likely to possess features that will increase the likelihood of success in further eradication efforts.

Infestation size

The smaller the infestation, the more likely eradication will be achieved.

Delimitation

Delimitation is a critical component for successful eradication. Incorrectly assessing the extent of infestations is a major contributing factor to the need to switch from eradication to another management approach, highlighting the importance of exhaustive delimiting surveys (see chapter 6 for more information on delimitation).

Monitoring rate

Infrequent monitoring is an important factor in the failure to eradicate. Increasing monitoring intensity and thereby locating hard-to-find individuals can substantially decrease the time taken to achieve eradication. Therefore, a long-term plan with consistent treatment and regular monitoring of infestations is crucial. The frequency of monitoring should be determined by how quickly undetected plants could reproduce.

Site accessibility

Sites may be difficult to traverse due to slope, rockiness, dense vegetation and/or surface water. This will slow down searching and control activities. There may be seasonal differences in accessibility (e.g. winter waterlogging).

Public perception

Eradication success is influenced not only by the species' biological factors, but also socio-political, economic and operational ones (Dodd 2015). Eradication planning needs to consider conflicts that could arise in the removal of specific plants. This may be a greater consideration for public land rather than private managers, for example the removal of emerging weeds that are valued by the public at popular sites on public land.

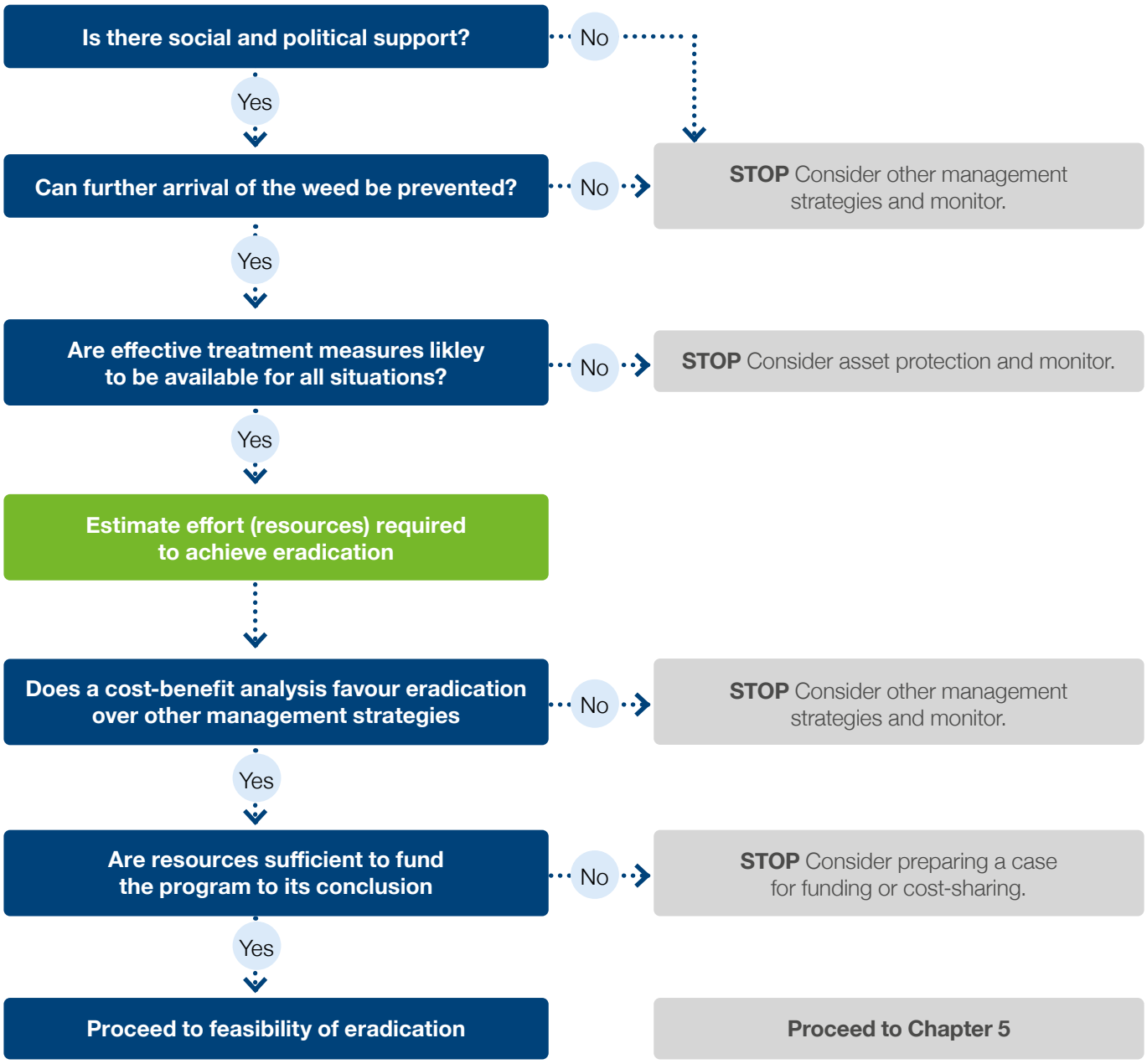
In the eradication response plan template (template 1), provision is made for analysis of public perceptions involved in the presence and removal of the target species.

When is eradication a suitable goal?

Chapter 3 was about weed risk and how this can be assessed. A risk assessment is a valuable tool for understanding more about how a weed might behave in the landscape and your chances of successfully controlling it, but weed risk is only part of the picture. There are other factors that influence the success, or otherwise, of an eradication response.

The process below (figure 20) guides you through the types of questions that should be asked to explore if a weed is a suitable candidate for eradication. Seek assistance from a weed professional (e.g. Landscape Board officer or agronomist) if you need help answering these questions.

Figure 20 – Suitability for eradication of weed candidates (based on Panetta and Timmins 2004)



Is there community and government support?

If the socio-political environment is not suitable, a weed is unlikely to be a successful eradication target. Social considerations include conflicts of interest surrounding the plant. For example, the plant may be used for timber or honey production, or it may be a popular garden plant. It could be used for habitat by indigenous wildlife. Gauge if there is likely to be social resistance.

Can you gather government agency support? What information do you need to build a case to obtain support? If you have followed the previous steps of this handbook, by now you would have completed a weed risk assessment, and this will provide a good foundational argument for pursuing eradication.

If there are multiple land management agencies or landholders involved over different land tenures, achieving eradication may be more difficult. It may provide opportunities – i.e. there will be a shared responsibility and there may be more resources – however if one agency or landholder 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?

This will determine whether eradication is achievable in the long term. If you know how the weed arrived, you need to consider if it can be prevented from happening again. If you can only assume how the weed arrived, you need to consider if it is possible to prevent spread along those pathways, or from sources where the weeds are likely to have come from. These pathways or sources may be on another land tenure, over which you may have little influence, or the weed may be dispersed by birds, which you have little influence over.

Weeds in cultivation and/or trade

In some 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, state-wide or regional level, but at the local level, eradication 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 land or within a buffer around the 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?

The aim of eradication is to remove/kill every plant and all propagules. This requires treatment techniques that are effective in all circumstances that the weed grows in. If techniques are not well developed or if off-label herbicide advice is required, delays or low efficacy can result in eradication failure.

If effective treatment methods are not available, then **STOP** and consider a different management approach and monitor.

Estimate effort (resources) required to achieve eradication

It is important to estimate how much an eradication program will cost. A more accurate calculation will have to be developed when you are in your planning stage, but some back-of-the-envelope calculations at this time will help you decide if progressing with eradication is realistic. Costs will include things like:

- control (e.g. chemicals)
- labour
- logistics
- surveying/delimitation.

Multiple visits to infested sites need to be factored in for weeds that are difficult to detect, reproduce quickly and produce long-lived propagules. You need to estimate how long you think you will need to continue the program. As a guide, an eradication program should continue as long as viable seed remains in the seedbank. For example, if the seed viability is six years, the program would need to continue for a minimum of six years after the last time that plant went to seed. It is also worth considering what your funding sources may be.

Once you start your delimiting survey (see chapter 6), you can calculate the area requiring treatment. It is probably better to overestimate the effort required, as the costs involved in eradication are generally underestimated. Models are available to estimate eradication duration and costs. 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, and therefore the right people to carry it through. You need to consider the following:

- Do personnel have the time to do the work?
- Is it as important as all the other tasks expected of them?
- Is the workload realistic?
- Are people expected to be in the field for extended periods away from their homes and families and other commitments?
- Do people 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?

Other commitments during peak periods (e.g. harvesting, crop establishment, breeding, fire management responsibilities etc.) can pull people away from an eradication response program, giving the weed sufficient time to grow and reproduce. Pre-planning for potential peak periods where clashing priorities may occur is advised and can be done by factoring in resources for additional staff or contractors that may be required to fill a short or long-term gap to maintain the response program.

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

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 an 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. In practice, the availability of resources required to complete an eradication program is likely to be the more critical aspect (see below).

If a cost-benefit analysis doesn't favour eradication, then **STOP** and consider other management strategies.

Are resources sufficient to fund the program to its conclusion?

If sufficient funding is not available, by working through these questions, you may have built a case to obtain funding.

If there are not sufficient resources to fund the program, then **STOP** and consider preparing a case for funding or cost-sharing – or consider a different management approach.

5 PREPARING AN ERADICATION RESPONSE PLAN

This chapter guides users through the process of preparing an eradication response plan. The suggestions, steps and scenarios can generally be applied across all land tenures and situations. Read on to learn more about:

- planning for an eradication
- why you should prepare a plan
- what to include in a plan
- the different phases of an eradication response plan.

What's involved in an eradication response?

Why prepare a response plan?

A plan for an eradication response gives a step-by-step guide to stopping the spread, preventing reproduction, and depleting viable propagules from areas occupied by the target species. Without a plan, operational activities may be poorly coordinated, lack logic and be deficient in key information. As eradication projects can run over long periods of time, an eradication response plan ensures that consistency is achieved if a change in personnel occurs. Achieving eradication of weeds requires a well-documented response plan that spans the expected life span of the project. Project review is essential and an adaptive learning process is strongly advised.

Planning phase – prepare a response plan

The theoretical concepts behind planning and running a successful eradication project are incorporated into the eradication response plan template (template 1). Completing the template provides a firm basis for planning and scheduling your project (figure 21). Information should be updated as it comes to hand or changes in approach are required through the adaptive learning process.

The eradication response plan template incorporates the following information:

- General weed information
- Site information (use a new template for each infestation)
- Infestation details
- Weed details – biology and life history traits
- Growth calendar
- Methods of control
- Treatment budget
- Management zones (where a site has multiple infestations each requiring different treatment approaches)
- Delimitation strategies
- Project objectives
- Movement control
- Trace forward/trace back
- Communications plan
- Hygiene requirements
- Monitoring phase
- Eradication assessment
- Site works plan

Operational phases and decisions in an eradication response

In preparing an eradication response plan, it is helpful to visualise the components of a response and the possible management outcomes. Figure 22 provides this visualisation, focusing on the main component of an eradication response – the operational phase. An eradication response comprises two operational phases:

- the *active management phase* to both continue to delimit the infestation and treat all known plants and new recruits to prevent seed set
- the *monitoring phase* to determine if further recruitment is occurring from the seedbank or budbank in the soil (Panetta 2007) (see figure 22) or if the infestation has expanded or spread.

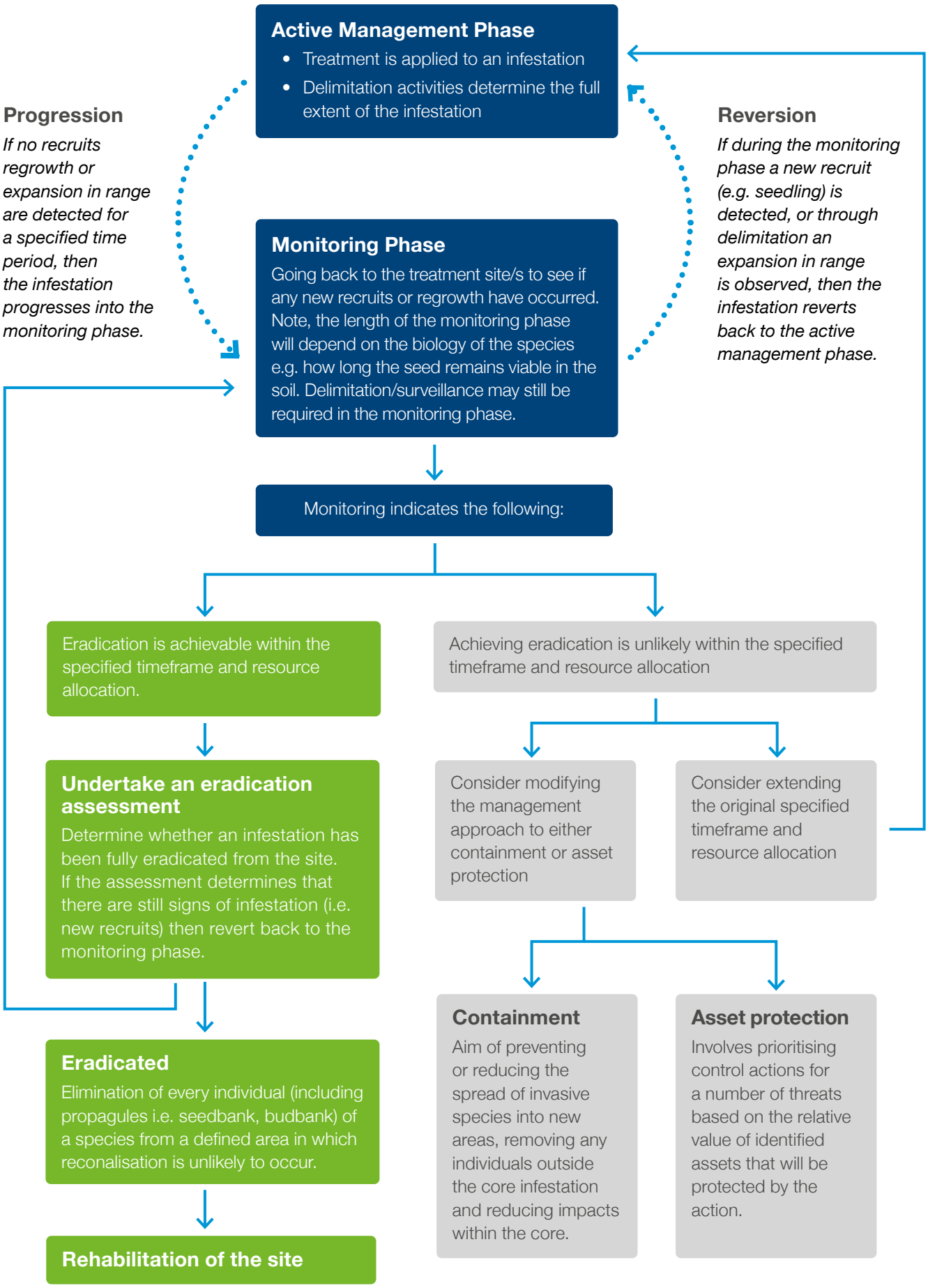
An eradication response remains in the active management phase while the infestation is still being delimited, and while there are still plants and propagules present at a site. A response plan should detail all the activities and methodologies you will employ to both delimit and treat infestations. These details and approaches may need to be adjusted throughout the response if new information, technologies or techniques come to hand. Delimitation approaches are discussed further in chapters 1 and 6, and treatments in chapter 6.

Once all infestations have been delimited and all plants and propagules are eliminated, the response enters the monitoring phase. The time it will take to enter the monitoring phase has been recommended to be at least 12 months (Panetta 2007), however, it will be largely dependent on the longevity of the soil seedbank and budbank. For example, if the weed's seeds are known to remain viable for two years, active management may be required for at least two years after the last time the plants set seed. These types of considerations in your response planning will increase the likelihood of success.

There is always some uncertainty when making management decisions, such as how long to continue active management. The monitoring phase allows us to cease active management while continuing to keep a watch on things just in case recruitment is still occurring or the weed has come in from somewhere else. An eradication response plan should detail what monitoring activities will be performed. It is important that the method used and the frequency is likely to detect any new recruits before they themselves set seed or can be spread. It may be necessary to come back periodically (e.g. once a year) and survey the area for new recruits. This level of detail should be in your plan. Monitoring is discussed further in chapter 6. Your plan should also include provisions to review your approach. If through monitoring, it is discovered that there has been recruitment, your plan should allow you to make the next management decision: either to revert to the active management phase and continue to work toward eradication, or adopt another management objective such as containment. This is a decision you will need to make based on your timeframe and available resources. Including review processes in your plan will make this easier.

Figure 21 – Preparing an eradication response plan will ensure all appropriate steps are taken to stop the spread, prevent reproduction and deplete viable propagules from the management area.

Figure 22 – Operational phases within an eradication response. Adapted from Bec James, DELWP Victoria, 2016



6 IMPLEMENTING A RESPONSE PLAN

Chapter 5 introduced the concept of the operational phases of a response (figure 22) and the decisions you have to make if you (i) continue to progress toward eradication, or (ii) adopt an alternative management objective (e.g. containment or asset projection). In this chapter we will explore the operational phase of an eradication response in more detail. Read on to learn more about:

- delimitation surveys
- why you should prepare a plan
- what to include in a plan
- the different phases of an eradication response plan.

Active management phase: delimiting the infestation

Often when we think of eradication, we focus on killing the weed where we know it to occur, but there is much more to eradication than just that. This chapter identifies two operational phases of the eradication program: the active management phase, comprising both delimitation and treatment, and the monitoring phase. Figure 22 shows the interaction between these phases and how they are used together to inform treatment and ongoing management.

What do we mean by delimitation?

The aim of carrying out a delimiting survey is to determine how far a weed has spread and if it is beyond the early stage of invasion. In an ideal world, this would be known before the eradication program is started. However this level of understanding is often incomplete, and we usually need to know more to be confident we are taking the right approach.

Depending on the scale of the weed infestation, delimitation can be a big job, and a reliable way to detect the weed is required. Carrying out a delimiting survey may also be dependent on the lifecycle of the weed or other factors such as climate. There may be several different land tenures or pathways of spread that need to be searched. All these factors may slow a response down, resulting in a missed opportunity for eradication.

The process described here assumes a level of delimitation has occurred prior to the eradication program starting and the results of a preliminary delimitation have helped inform the management decision.

It is proposed here that delimitation activities continue throughout the eradication program, to ensure that eradication remains a realistic management objective.

What is the difference between delimitation, search and surveillance?

Searching is the act of actively or passively looking for a weed and can be used interchangeably with the term **surveillance**, though the latter usually implies that the search is more structured with a documented and repeatable methodology. Searching and surveillance can be performed for a number of purposes, either in prevention, or looking for a weed or confirming its absence.

Delimiting is the act of searching for a weed with the aim of determining the full extent of the infestation. A weed is delimited using search techniques, therefore, this section refers back to search methods discussed in chapter 1 of this handbook.

Why do I need to undertake a delimiting survey?

The boundary of a new weed infestation needs to be confirmed, so a decision can be made on whether to continue an eradication program. It also provides clarity on the scale of the task ahead and the resources required to survey and treat the infestation. Delimiting allows for a more accurate calculation of cost and logistical considerations and timeframes, and should continue throughout the active management phase of a response.

Delimitation is important because it gives you knowledge about the extent of your infestation and allows you to make informed decisions about ongoing management.

Types of delimitation

Pathway analysis, trace forward and trace back

A **pathway analysis** identifies invasion pathways (for both deliberate and accidental introductions) and assesses the degree of risk associated with each and the management options needed for high-risk pathways. It involves identifying the characteristics of how the target weed spreads i.e. the vectors it utilises to spread in a landscape. Refer to resource 3, figure 4 and figure 23 for examples of vectors and pathways of spread and where to focus search efforts.

The next step is to **trace forward** from an identified infestation and determine where else the target weed may have spread to. Then, if possible**, trace back** to where you think the weed may have come from (the source).

Trace forward and trace back are usually related to human-assisted transport of weeds, both deliberate and unintentional. These terms are more commonly used during biosecurity emergency responses but can also be used by land managers when considering the arrival or spread of weeds into and from an area. Tracing dispersal by natural means such as wind, water or wildlife is usually concerned with much shorter distances than dispersal via human-assisted transport.

Using the information collected on the pathways of spread and the trace forward and trace back investigation, identify which of these will be your highest priority when searching for the target weed and factor this into deciding where the search areas will be. It may also be worth considering refining the search areas to make them practical when out in the field. For example, use roads, rivers, streams, land marks etc. as the boundaries of your search areas.

Factor into the search areas any species that can disperse over long distances such as olives carried by birds or fleabane carried by wind. These are the most unpredictable and can result in plants being located in new and unexpected parts of a landscape.

Once you have identified the search areas within your site, draw these on a map and include this in your search plan (refer to template 2).

Figure 23 – Examples of sites and sources where weeds may occur.

From top to bottom: Fountain grass (Cenchrus setaceus) along a railway line; pine cone cactus (Tephrocactus articulatus) in a reserve abutting a residential property; brown spined Hudson pear (Cylindropuntia tunicata) occurring at an old dump site; Pampas grass (Cortaderia spp.) at an old quarry site. Photos: Shannon Robertson and Troy Bowman, Department of Primary Industries and Regions

Structured surveys

Targeted surveys

A targeted survey is a detailed, small-scale survey that is conducted in areas of a delimiting survey where close attention is required i.e. areas that have had previous infestations of a target weed. In conducting this type of survey, you can have a thorough look for any infestations that may have arisen from a core infestation or would be likely to have been missed (i.e. off-road network, secluded area).

In general, a targeted survey is carried out by two or more people, walking straight lines (transects) approximately 5–10 m apart (depending on the detectability of the target and obstacles in the way), scanning the ground for any of the targeted plants as you walk along. Flagging tape can be used to designate completed transects as you walk, or you can follow along using an appropriate mobile app.

Surveys of larger areas

Remember, the purpose of a delimiting survey is to determine the extent of the infestation. Ideally, you want to survey all suitable habitat in an increasing radius out from the known infestation. You can use your pathway and trace forward/trace back searches to help inform the search area. Again, scale comes into play here: if you are only working at a property scale, your ability to search beyond the property might be limited. However, not knowing the extent of the weed outside the property may impact on your ability to stop the weed coming back in after you have removed it from the property. This is certainly something to consider.

Examples of search methodology are discussed in chapter 1 and further in McNaught et al. (2008). These methods can be applied to a delimitation survey.

The type of delimiting survey you chose will depend on various factors including the:

- size of the area you need to search
- terrain/accessibility of the search area
- vegetation type of the search area
- habit and how conspicuous the weed is in the landscape
- distribution of ground cover.

Refer back to chapter 1 for examples of search techniques and their effectiveness and suitability.

When a single plant or infestation of your target weed is located during a ground-based survey

When an infestation or single plant is found, mark it with your GPS and flagging tape (if appropriate) and record its details using the field recording template (template 3). Then walk about five or so metres from the newly found infestation in a circle searching for further plants. Hit the GPS every time you see the plant. If you haven't seen any more plants in about 10 minutes of searching it might be safe to say that it is an isolated infestation. If you keep finding more infestations, then a targeted survey should be carried out to ensure all likely infestations are located (see above). Further information on how to collect a GPS point and place a marker (flagging tape) can be found in resources 6 and 7.

Estimate how long you think the weed could have been at the site. This can be done by estimating the age of the discovered plants and the number and age of the subsequent generations it may have produced. Land managers or neighbouring properties may also have knowledge of when they first saw the weed. Collecting this information is useful when deciding where to expand the delimiting survey. For example, if a satellite infestation contains mature plants this may indicate the need to expand the search area or re-evaluate the survey plan. Record this information on your field recording template (template 3).

Remember to take photos of any infestations or other areas of interest, record locations using a GPS and geotag the images (see resource 9).

Logistical and physical constraints

The ideal scenario is to be able to search all sites in all areas for the target weed. However, in many delimiting surveys, as discussed above, this is not possible due to the costs and the limited resources available. Below is a list of some of the logistical and physical constraints that may impede your survey, or at least need to be considered:

- budget
- resources
  - » people
  - » vehicles and survey equipment
  - » specialist knowledge for plant identification
- access to survey area (i.e. permits, permission from landowner, keys to locked gates)
- wellbeing and safety e.g. fire season, flooding, heat, cold, steep slopes, mine sites, snakes, tides in coastal areas, mobile phone reception.

When planning, it is also important that any permits or permission for access are obtained by the relevant authority or landowner prior to undertaking the survey. Permits for moving declared weed specimens also need to be taken into account. See step 8 of chapter 1 for more information.

Quick guide to planning and performing a delimiting survey

A delimiting survey requires pre-planning in order to maximise the likelihood of detecting the target weed within the search area. Some of these steps may have been done to inform the WRA. This section lists four steps that will assist in planning and undertaking a delimiting survey.

If you are planning a delimiting survey from scratch, follow this guide in its logical order. Alternatively, you can go to the relevant section of the guide for the advice you require.

Figure 24 – Steps to planning and undertaking a delimiting survey

Step 1. Get to know your weed

To determine the true extent of a weed in the landscape, you need to know what it looks like and the times of year and growth stages where you are going to be able to definitively recognise it. Ideally, you will be familiar with the species well before you start a delimitation survey. This step is to remind you of some of the important things that need to be considered regarding the weed's biology and ecology.

Involving an expert familiar with the species as early as possible is recommended, so that they can pass on their knowledge and advice on timing and aspects of delimitation and management. If there are significant gaps in knowledge, you may have to run with what you know, but if possible involve researchers, so that these gaps can be addressed as you go and new learnings incorporated in the response as appropriate.

Weed characteristics that will inform delimitation include:

- seed longevity, seedbank and budbank
- identification characteristics (e.g. figure 25) so you can make a confident identification in the field
- method of reproduction e.g. seed and/or vegetatively (i.e. via suckers, bulbs, corms)
- annual growth cycle (e.g. when does it flower? Is it dormant below ground during certain seasons?)
- how long the plant takes to reach maturity
- dispersal mechanisms (e.g. attractive fruit, barbs)
- dispersal vectors (e.g. wind, water, vehicles, birds, foxes)
- habitat suitability (e.g. does the target plant prefer shade, riparian areas, disturbed areas, open areas, frost free habitats etc.?)
- particular conditions that would make it easier to find in the field e.g. flowering period, or leaf colouration at certain times of the year.

Most importantly you need to be able to identify the weed. Information on how to identify a plant can be found in chapter 2. Figure 25 shows some of the ID characteristics to look for.

Figure 25 – Photographs of the characteristics that are useful for the identification of a plant. The plant shown above is mesquite (Prosopis sp.).

From top to bottom: whole plant; flowers; stem and leaf arrangement; seed pods. Photos: Shannon Robertson, Department of Primary Industries and Regions

Step 2. Plan the search

Review any past records or earlier botanical survey plans and results

Investigate whether there have been any previous sightings or recorded information of the target weed or any other weeds in the immediate and surrounding areas. Databases and sources of information that should be checked include:

- sources listed in resource 1
- herbarium specimens and records
- local databases, spread sheets, maps, geographic information system (GIS) layers, works plans of weed infestations, note books, filing systems
- local management plans (e.g. reserve, forest, park, property etc.) that may include weed lists.

In the office/home

Design appropriate delimitation approach

Using information gathered on potential distribution, logistical and budget constraints, pathways and various search methodologies, design a search that suits your circumstances. Remember that the aim is to find the boundary of the infestation and to concentrate the survey effort to the areas most favourable for the plant.

Complete search plan template

To assist in completing the steps outlined in this guide, fill out the search plan template (see template 2) for your target weed and for the site where you want to carry out the delimiting survey. The completed search plan will help you become familiar with the biology and ecology of your target weed and characteristics of the site.

Create maps to take out in the field

Creating a variety of maps to take out in the field will greatly assist in orientating yourself at the site, identifying areas that may need to have a targeted survey undertaken (this is explained further in the structured survey section at the beginning of this chapter), and identifying any correlations between the presence of the target weed and factors such as vegetation type, land use etc.

A list of useful maps to take out in the field includes:

- location of the search areas within your site
- locations of previously recorded infestations of the target species
- the land status of the site, including its boundaries and adjoining land use
- an aerial photograph of the site to draw on in the field.

Pre-load data onto a GPS

Load the road network, property/parcel boundaries and any previous recording of your target weed onto your GPS. This will make it a lot easier when orientating yourself in the field and in relocating previous infestations of your target weed.

Equipment to be used for the delimiting survey

Gather all of the equipment you require to perform a delimiting survey. A list of suggested equipment can be found in resource 8.

When to survey

A delimiting survey should be planned for good conditions and with sufficient time allowed. A rushed survey due to lack of time, failing light conditions or poor weather is likely to result in an incomplete survey. Revisiting to complete the survey is not efficient. Long-term weather forecasts make it possible to predict weather conditions for field work. Also allow sufficient time to photograph the plants.

The best time to look for a weed is when the growing conditions are ideal and the plant is flowering or exhibiting some other form of growth that makes it easy to see e.g. brightly coloured fruit or spines that are easy to see against a low sun. However, this might not be the case when a weed is first found (e.g. during winter), so it is important to get your ‘eye in’ on the weed under less than ideal conditions.

Other factors to consider that may affect the timing of the commencement of a survey include:

- accessibility and availability of resources (i.e. people, vehicles)
- timing of other activities (i.e. planned burning, harvesting)
- seasonal growth of surrounding plants
- flowering of other co-occurring plants that are similar to the target weed.

Step 3. Performing the delimiting survey

This is where all your pre-planning will pay off! Use template 2 to help collect information and record data. You may also want to refer back to your eradication response plan template (template 1) to help populate some of this information.

Step 4. Making sense of the data

Collation of collected data

After the survey is completed, store and organise your survey data ready for analysis. Make sure others know how to access this information if necessary.

Analysis of data

Considering the data captured from a delimiting survey is an important step in understanding what you have found and what influence this may have on your eradication response. The results should be interpreted with respect to the aim of the survey and why it was established in the first place.

The main reason for carrying out a delimiting survey is to determine whether the target weed is at the early stage of invasion. The results (raw data) of a delimitation survey can also be used to:

- produce a distribution map
- help determine the management approach for the weed (e.g. is eradication feasible?)
- identify trends in the movement and spread of weeds in the landscape
- identify trends in location and species e.g. a species mainly present along waterways
- develop a cost-benefit analysis relating to the time spent undertaking the survey and the value of the data created (McMaugh 2005)
- calculate basic statistics
- review and make recommendations for further survey work, future management actions and priorities, including adaptive management to influence changes in management approach.

Comparisons can be made as to whether the results confirm or contradict the expected outcomes. Consider value adding to your data by collaborating with other individuals or groups. It is important to remember that delays in analysis are likely to result in delays in treatment.

> Remember that delimiting surveys should occur until you are confident you know the full extent of the weed and that their purpose is also partly to inform progress and allow you to evaluate if you are on track with your objectives.

Consider the following:

- If you find new infestations, their location will have to be added to your treatment list. You may have to prioritise sites for control purposes, or depending on the number of new infestations found, you may have to reconsider whether eradication is still a feasible objective.
- If you don't find any new infestations – GREAT! You can concentrate on the known infestations, but still keep looking at other places to widen your search and increase the certainty that you have delimited the entire extent.

Reporting the results

Don't forget other people may be interested in the survey results. These are likely to be the same people you contacted regarding permission or permits to access survey areas. Neighbours may be especially interested. They will be glad to know if you have only found a small infestation, and similarly, they may be concerned and want to take action if you have found more of the weed than expected. See the communication and engagement section of this chapter for more information.

Active management phase: undertake treatment

The purpose of treatment is to remove all known plants and prevent reproduction and recruitment.

There are a number of methods available to treat weeds and choosing the most suitable option will depend on the:

- species that you are dealing with and best practice control options available
- scale of the problem
- resources available
- time constraints
- situation and location of the weeds.

Integrated weed management

Integrated weed management (IWM) is the coordinated use of a range of appropriate weed control options including physical removal, chemical control, biological control and cultural control to achieve effective long-term control, or in this case, eradication of the weed. The best results will be achieved by combining treatment methods that take into account the weed's biology and ecology and site conditions.

At all times integrated management of weeds needs to be considered in the broader context of management for biodiversity or production systems, taking into consideration the ecology of the ecosystem being protected and the off-target impacts and consequences of the combination of weed treatment techniques used.

Each treatment will need to be tailored to the specific location for maximum efficacy and safety. The best eradication strategy will probably combine cultural and chemical treatments, but should include alternative methods in case the primary treatments fail. An example is the use of fire to kill standing plants and reduce weed biomass. Regrowth after fire is treated with herbicides, with improved access and often with improved detectability.

Wherever practicable, treat weeds on-site and aim to leave weed biomass there. Transporting removed weeds or contaminated soil is challenging: there is a risk that propagules will be spread, disposal of the material can be problematic, and it is more costly.

Integrated management requires long-term planning, knowledge of the weed's biology and ecology, and weed treatment methods (Ensbey 2014).

Tips for successful weed control

Prevention is cheap

- ensure vehicles, machinery, livestock and produce do not carry weed seeds
- report sales of declared plants to your local Landscape Board or Department of Primary Industries and Regions
- pay particular attention to Alert Weeds – most have yet to become widely established in SA.

Find weeds early

- get to know plants in your area/on your property and quickly identify and deal with new threats.

Watch your spread

- take measures to contain weed infestations and prevent further weed dispersal.

Plan your controls

- obtain information about managing your target weed – timing, herbicides etc
- map infestations
- treat weeds when they are young
- use recommended control methods. Minimise damage to non-target plants. Establish and promote competing vegetation.

Undertake follow-up control

- continue follow-up treatments over several years. Some plants may have been missed, some may not have died and new seedlings may emerge.

Preventing seed set for as long as the life of the seedbank is the only way to eradicate weeds from the management area.

Note on seedbanks and budbank

Given that local eradication is the elimination of every single individual element (including propagules) of a species from a defined area in which recolonisation is unlikely to occur, response plans need to take into account seedbanks and budbank. Under the ground, there may be long-lived seed and vegetative propagules e.g. root fragments, rhizomes, stolons, bulbils and tubers. Consider how long these propagules remain viable in the soil before ceasing the monitoring phase of an eradication response plan.

In some situations, propagules in the soil can be stimulated to germinate/grow, exhausting the seedbank and budbank and allowing the resulting new plants to be treated with a suitable technique.

For specific advice on treatment, refer to the current edition of the *Weed Control Handbook for Declared Plants in South Australia*.

Minimising weed spread

One of the most common ways in which weeds are spread is via vehicles and other machinery that have travelled through an infested area. The easiest way to prevent this spread is to thoroughly clean vehicles and machinery before leaving a site. The most effective cleaning options include:

- air blasting hard-to-reach spots such as cavities and joints while the vehicle and any contaminants are still dry
- washing the vehicle down using a low- or high-pressure cleaner, or a spray tank and pump. A commercial car wash will also remove the majority of weed seeds. Clean the vehicle from the top down. Spray the tyres and move the vehicle forward to ensure the whole tyre is clean
- vacuuming inside the vehicle cabin to remove contaminants
- using a brush or scraping implement to remove contaminants such as burrs and clods of mud from machinery tyres or vehicle tyres.

Also consider:

- using detergents to assist the removal of grease, dirt and mud, which may contain weed seeds
- cleaning the undercarriage, springs and axles of trailers
- for boats, checking the floor and sides, propellers, anchor wells, cooling system inlet, bilges and bait wells
- cleaning footwear and removing weed seeds from socks and other clothing
- using the same site for cleaning and monitoring it regularly for weeds.

Contaminated material must be disposed of in a way that ensures all weeds and seeds removed cannot disperse or grow.

Monitoring phase

The monitoring phase commences when no recruits or regrowth have been detected in the area subjected to active treatment. An arbitrary period of time is required to determine this transition point, recommended to be at least 12 months (Panetta 2007). The monitoring phase reverts to the active management phase if plants are detected (refer to figure 22 in chapter 5). There are other forms of monitoring, depending on the purpose. This includes monitoring production and biodiversity for changes associated with weeds.

How often a site is monitored should be determined by how quickly the target species may reproduce – an important piece of information for the eradication response plan (Panetta 2007). When determining how often to visit a site, keep in mind the possibility that sometimes small plants will escape detection and could possibly reach maturity before the next visit.

Inconsistent site visitation has limited the progress of many eradication programs.

Communication and engagement

Communication and engagement are important components of all management approaches. Effectively engaging with neighbours, government agencies, community groups and other stakeholders is essential for the success of weed management.

Develop a simple communication plan and keep it updated. Include contact details and a simple schedule of frequency and ways in which to communicate with interested stakeholders (e.g. weekly phone calls, six- monthly emails, annual newsletters etc.) to keep them informed about your search and eradication efforts, including good and bad news of progress (figure 26, page 57).

Reporting the results

It is important to report and communicate any findings or recommendations from the eradication response to the appropriate people. These may include:

- team members
- manager
- land manager/owner
- sponsor/investor
- steering/working group
- community groups
- neighbours.

In doing this you could help generate potential funding or increase the interest in the weed. If communication is done early enough it may stimulate reports of the target species on land bordering the area where you are working, which could assist with the success of your work.

Assessing progress towards eradication

Because eradication efforts can be expensive and will divert resources from other management activities, it is important to get a sense of whether eradication is likely, or whether the program might be evolving into an indefinite control effort. Regular searching and record keeping are required to properly evaluate an eradication program. If infested sites do not advance from the active to the monitoring phase within a timeframe equal to or less than the seedbank longevity of the target weed, this should be a cause for concern. Additionally, if it hasn't been possible to prevent reproduction of the target weed, eradication may need to be reconsidered as a management goal.

Where there are multiple infestations, combining the times since detection of the target species for each site into frequency distributions (% of total infestations) is a useful way of demonstrating progress towards eradication (Panetta 2007). For example, 40% of the sites may be in the active phase, 30% may have been in the monitoring phase for one year, 20% in the monitoring phase for two years and 10% in the monitoring phase for three years. Progress towards eradication will be reflected by few (if any) sites remaining in the active phase and a shift towards longer times in the monitoring phase. Where seed persistence is likely, time without the appearance of seedlings may be viewed as to how long the seedbank would be expected to persist; this also provides an indication of progress towards eradication.

Reductions in target plant (including seedling) numbers over time will be favourable indicators, but remember that the aim is to achieve zero density of the target, and certainly to prevent reproduction by any new plants that appear.

Declaring eradication – how can we be sure?

A simple indicator that eradication has been achieved is when the target species has not been detected for a period equal to or greater than its seed longevity (Regan et al. 2006; Dodd et al. 2015). The longer the time, the more likely the weed has been eradicated (Bekker et al. 1998). Trends in seedling numbers provide some indication of the condition of the residual seed bank. However, caution is needed for species with deeply dormant seed or bud banks, and where variation in seed longevity occurs between environments.

What can go wrong when declaring eradication?

There are two ways that the decision to declare a weed as eradicated can go wrong. The first is when a species has not been sighted for some time, eradication is declared and monitoring is stopped, but the species is still present and can spread, which may incur large economic and environmental costs. Alternatively, searching may continue after the species has been eradicated and therefore scarce economic resources are wasted (Regan et al. 2006).

Rather than rely on declaration of eradication based on an ad-hoc criteria, such as after three or five years without detection, ideas of seed bank longevity, or by setting arbitrary thresholds of 1% or 5% confidence that the species is not present, an alternative economic consideration has been proposed. This suggests we stop looking for the target species when the expected search costs outweigh the expected benefits.

While this approach is practical for species with definable economic impacts (e.g. agricultural weeds), since a weed cost estimate is required, the approach is of limited use for environmental weeds, where economic impacts are notoriously difficult to estimate. Despite this limitation for environmental weeds, taking into account the potential cost of damage to the environment should eradication fail, versus the cost of the monitoring program, can assist managers to decide when to terminate weed eradication programs.

Even when a program is declared successful, occasional visits to previously infested sites will pick up a resurgence in the weed population before much further spread has occurred. This was certainly the case with the eradication program targeting bitterweed (*Helenium amarum*) in south-eastern Queensland, where the weed was detected in one of its sites five years after eradication had been declared.

Figure 26 – Discussing surveillance approaches and outcomes on site with land managers.

Review

This document focuses on the eradication response. The decision to commence an eradication response is based on the information available at the time and as an eradication response proceeds it is frequently found that new information emerges e.g. additional infestations are found, or 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 need to be halted after a short time – be prepared for this possibility.

An eradication response plan should be reviewed regularly throughout the active treatment and monitoring phases and your management adapted as appropriate. Figure 22 in chapter 5 acts as a good reviewing tool by showing the eradication process from commencement through to outcomes, and the points at which a review may be required to inform the next management decision.

A review will almost always assess:

a) the success or otherwise of treatment

b) the length of time it is taking to achieve eradication

c) if the infestation is truly delimited or if it continues to expand

d) the continued resources available to accommodate any changes in a, b or c.

Table 10 lists scenarios that may trigger a review of the eradication response.

Table 10 – Possible situations that may trigger a review of the eradication response

Scenario/trigger for review	Type of review/What a review may find
No increase in infestation size/number of sites despite increasing area delimited	You may have completely delimited the infestation, meaning you can concentrate more on treatment and monitoring
Infestation size/number of sites continue to increase as you delimit	The infestation may not be fully delimited. Review feasibility of continuing eradication response based on cost implications (treatment, personnel, logistics) for eradicating a larger area.
No new sites found or recruitment recorded	Review when to transition into monitoring phase.
New recruitment found during monitoring phase	Review feasibility of reverting to active management versus changing management objectives to containment or asset protection.
No new plants reported for a period equal to or greater than the seed viability of that species	Conduct an ‘eradication assessment’. It may find that the weed has been eradicated.

Summary

By following the latest best practice methods for managing weeds at early stage of invasion, land managers have the best chance of successfully eradicating them from the management area. Eradication of weeds will prevent the need for ongoing, long-term management. This will save time and money while increasing farm productivity and preserving the biodiversity assets of our natural environments.

Sharing information and seeking assistance will ensure we are in tune with local issues and share the collective burden of weed management. Ultimately, the community as a whole benefits from weed management practices that prevent recently established weeds becoming widespread.

Appendices

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Glossary

Absent, absence data: Locations searched where the weed was not observed. These data provide a record of effort expended on searching, help in the planning of future searches, and are useful in quantifying the spread of an infestation over time (MacKenzie et al. 2002).

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).

Biosecurity: A process designed to mitigate the risks and impacts to the economy, the environment, social amenity or human health associated with pests and diseases (Victorian Government 2010).

Budbank: Dormant meristems (buds) formed on rhizomes, corms, bulbs, bulbils and tubers in the soil able to grow and produce new plants (Harper (1977) Population biology of plants, Academic Press, London)

Buffer: An area around, in this case, public land in which weeds are searched for and treated to prevent them reaching the public land. The radius of the buffer could be hundreds of metres to 5, 10 or 20 km depending on the situation.

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).

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 2016a).

Declared plants: weeds that are regulated in South Australia under the *Landscape South Australia Act 2019* due to their threats to primary industry, the natural environment and public safety.

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).

Desk-top search: A search that focuses on data sources such as weed databases, publications and spatial or mapping systems, in order to compile distribution records or observations of a weed or list of weeds in an area. They typically are carried out on computer or through publications while at a desk, and increasingly anywhere with mobile technology. The desk-top search is a component of structured (active) searching.

Detectability: The probability of a particular target individual being detected using a particular sampling technique (Hester et al. 2010).

Drone: See 'unmanned aerial aircraft'.

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

Early stage of invasion: Where plants have naturalised and are beginning to spread. Since spread has just begun, such plants are not widespread and are generally only encountered by chance, unless specifically targeted by search efforts. Coordinated intervention, i.e. eradication or containment is at its most feasible for plants in this stage of invasion owing to their highly restricted distributions (Panetta 2016).

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).

Established: A species that, for the foreseeable future, will perpetuate within an area after entry (Victorian Government 2010).

Farm Biosecurity: a set of measures designed to protect a property from the entry and spread of pests and diseases. farmbiosecurity.com.au/

Habitat: The kind of place in which a plant grows (FloraOnline 2010).

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 2016a).

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 2016a).

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

Introductory pathways: See 'pathways'.

Invasion: The process of spread (see 'invasive plants'). The propensity to spread (invasiveness) is one of the two components of weed risk assessment, the other being impact. It is important not to confuse these two components (Panetta 2016).

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).

Line survey: A survey often along a linear feature such as a roadside, and defined by start and end coordinates.

Look-alikes: Plants that look similar and can be confused with another species of plant (Blood and James 2016a).

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).

Opportunistic search or detection: Casual, chance observation, where searching is not planned or carried out deliberately but detection of a weed occurs incidentally while undertaking another, unrelated activity. Also known as passive, casual, incidental or ad-hoc search or detection.

Pathogen: An infectious agent such as a virus, bacterium, prion, fungus, viroid, or parasite that causes disease in its host (Reference viewed online 8/1/2021: 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).

Pathway analysis: Identifies the invasion pathways (for both deliberate and accidental introductions), assesses the degree of risk associated with each and the management options needed for high risk pathways. Pathway analysis also identifies weak links in the invasion pathways and the species which use high risk pathways (Downey et al. 2010a).

Pathway focus: A search that concentrates on pathways of introduction and spread for a suite of weeds.

Point location: A pair of coordinates used to pinpoint a location.

Polygon: A number of joined spatial points representing an area when the first point is joined to the last.

Present, presence data: Information collected to indicate that, in this case, a weed exists at a location.

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

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.

Remote sensing: The process of using non ground-based techniques such as aerial photography, multispectral airborne sensors; satellite imagery for surveillance (Hester et al. 2010).

Glossary continued

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).

Search areas: The specific area(s) within the site that will be actively searched during the survey for the target weed. These may be vegetation communities, or high risk locations such as roadsides (James and Blood 2016).

Search frequency: How often an area or site is searched. This should be designed to have the best chance of detection before the weed has a chance to reproduce.

Search intervals: Time between subsequent searches; should ideally be short enough to ensure weeds are detected before they have a chance to reproduce.

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.

Site focus: Consider all the weeds on an area of public land to work out the highest priority for eradication.

State prohibited weeds: Either do not occur in Victoria, or are present and can reasonably be expected to be eradicated. State Prohibited Weeds are the highest category of noxious weeds under the Catchment and Land Protection Act 1994.

Structured search: A deliberate and systematic search for a weed within a defined area (Harris et al. 2001). This approach is usually targeted at a particular species or a group of weeds that are likely to occur within a geographic location and can consist of a formal, repeatable method. The search may be conducted in the field or when looking through information about the area. Also known as an active, strategic, formal or targeted search.

Surveillance: The collection, collation, analysis, interpretation and timely dissemination of information on the presence, distribution or prevalence of pests or diseases and the plants or animals that they affect (Hester et al. 2010).

Target survey area: An area within the search area that is intensively surveyed (detailed small scale survey), especially during delimiting surveys.

Threat: Describes a possible danger (or exposure to harm), combined with the likelihood of that harm occurring to the native species present, without describing the nature of the threat (Downey et al. 2010b), i.e. anything that could conceivably cause damage to something we value is a threat. Threat identification is broader and more all-encompassing than risk assessment.

Transect: A straight line used during surveys.

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

Unmanned aerial vehicle: An aircraft without a human pilot on-board. Its flight is controlled remotely by a person or autonomously by on-board computers. Also known as drones or remotely piloted aircraft (Reference viewed online 8/1/2021: en.wikipedia.org/wiki/Unmanned_aerial_vehicle).

Vector: Something that carries, in this case, weed propagules.

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 focus: A search that focuses on a specific weed.

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.

Weeds at the early stage of invasion: See 'early stage of invasion'.

Abbreviations

ALA Atlas of Living Australia

APC Australian Plant Census

APNI Australian Plant Names Index

App application

AVH Australasian Virtual Herbarium

CLM Crown Land Manager

DEW Department of Environment and water

DPTI Department of Planning, Transport and Infrastructure

ED Early Detection

EIS Environmental Information System

EPIRB Emergency Position Indicating Radio Beacon

et al. and others

FIS Flora Information System

GBIF Global Biodiversity Information Facility

GIS Geographic Information System

GPS Global Positioning System

id, ID identification

IPNI International Plant Names Index

ISSG Invasive Species Specialist Group

IUCN International Union for Conservation of Nature

ISU Invasive Species Unit

PDA personal digital assistants

UAV unmanned aerial vehicle

URL Uniform Resource Locator

Weeds CRC former Cooperative Research Centre for Australian Weed Management

WONS Weed of National Significance

WRA Weed risk assessment

For more weed resources and information go to

pir.sa.gov.au/weeds

Templates and resources available online include:

Resources document, Eradication response plan template, Search plan template, Field recording template for weed searches and Field recording template for opportunistic sightings and herbarium specimens

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