Riparian

Weed management in riparian areas: south-eastern Australia

CRC Weed management

Australian Government
Land & Water Australia

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Front cover inset: Blackberry infestation along Fifteen Mile Creek, north-east Victoria.
Photos: Trevor Hunt DPI Victoria

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Introduction

Weeds in riparian areas

Riparian corridors are particularly susceptible to weed invasion and are often invaded by multiple weed species. This susceptibility to invasion is a result of the natural disturbance processes associated with flooding, favourable environmental conditions and the continued input of weed propagules from upstream and adjacent areas. The impacts of human activities have also increased the likelihood of weeds establishing in riparian areas. However, well designed weed management programs can achieve positive outcomes in riparian areas.

Purpose of this document

These guidelines are designed to provide assistance to managers of riparian areas in planning their weed management programs, and in so doing, highlight some of the challenges inherent in riparian weed management. Background material about riparian areas and the weed species typically found in them is provided. The steps required to develop an effective riparian weed management program are described. These steps outline general principles but do not provide management prescriptions for individual weed species or riparian sites. As there is considerable variation in riparian areas across Australia, these guidelines focus on the types of river systems predominantly found in south-eastern Australia.

While complementing other recent weed management guidelines (for Victorian examples see 'Further reading' section), the information in this document highlights the central role played by water flow, particularly flooding, in shaping riparian areas and their weed management.

'Controlling weeds in riparian areas is one of our most difficult and costly environmental management challenges, and successes are hard won.'

Charlie Pascoe, Manager Environmental Programs, Alpine District, Parks Victoria

Healthy riparian forest on the Barwon River, Otways, Victoria.
Photo: Fiona Ede DPI Victoria

1. Features of riparian areas

Defining riparian areas

Riparian areas are the terrestrial areas of the landscape which are adjacent to rivers and other water bodies. They can be defined in a number of ways, including:

The area of land that adjoins, regularly influences, or is influenced by, a river.

The principles outlined in this guide relate to riparian areas associated with rivers, but some of the principles can be applied to land adjoining lakes and wetlands.

The full extent of a riparian area varies with topography and may change along the course of a river. Deeply incised reaches generally have very narrow riparian areas with steep banks, while in other reaches riparian areas are flatter and more extensive. Some riparian areas extend some kilometres from the main river channel. These areas are often referred to as floodplains and may include old river courses.

The influence of flowing water

Rivers are dynamic physical systems that in turn produce dynamic biological communities. The flow of water moves sediment and other materials through the river corridor. There is frequent disturbance of the terrestrial physical environment due to changes in water flows, especially during flood events which redistribute sediment, eroding it from one part of the river corridor and depositing it elsewhere.

This frequent disturbance and redistribution of materials in the riparian area results in a complex mosaic of patches with different physical features. These patches provide a wide range of microsites which in turn support a diversity of organisms, both plant and animal. In addition, there are strong interactions between the terrestrial and aquatic parts of the system, for example through the development of complex food webs incorporating organisms from both environments.

Summary point

The dynamic physical environment of riparian areas creates opportunities for the development of highly diverse biological communities.

Landscape connections

Forming long, narrow, linear corridors, riparian areas connect different parts of the landscape. Although they often occupy only a small portion of the total land area, riparian areas are extremely important in landscape-scale processes as they allow the movement of energy, materials and living organisms through the landscape.

Native riparian vegetation

The composition of native riparian plant communities varies with location and environmental factors. The increased soil moisture levels in riparian areas favour the development of particular communities which may differ quite considerably in composition from those in adjacent upland areas, particularly if these areas are much drier.

Riparian vegetation communities influence both the biological and physical components of the system.

They do this by:

- providing food and habitat for terrestrial and aquatic organisms
- providing refuge for organisms during times of drought
- affecting water temperature and light levels
- affecting water quality by trapping sediments and nutrients
- influencing bank stability, sedimentation and erosional processes
- influencing hydrology by affecting overland and subsurface flows.

Summary point

Riparian vegetation influences a number of ecosystem processes with riparian corridors connecting different parts of the landscape.

2. Weeds in riparian areas

Definition of a weed

In these guidelines, a riparian weed is defined as a species which is not locally indigenous and which has the potential to negatively impact on some part of the riparian system. Thus plant species which are indigenous in one locality can be considered to be weeds in other localities. In particular, plants which require some form of action to reduce their potentially harmful impacts are considered weeds.

Invasibility

Riparian areas are prone to weed invasion for several reasons:

1. high edge:area ratio
2. favourable environmental conditions
3. flood events which cause frequent disturbance and move weed propagules
4. high levels of human activity.

As linear corridors in the landscape, riparian areas have long edges which provide multiple entry points for weed propagules. Edge effects are particularly important for riparian areas where the surrounding vegetation has a high environmental weed load, such as productive land and urban / peri-urban interfaces. Weeds also disperse along the river corridor through water movement and so riparian areas are subjected to propagule pressure from both the terrestrial and aquatic edges.

The environmental conditions in riparian areas are often more favourable to plant growth than those in adjacent areas, particularly in the drier parts of south-eastern Australia. Soil moisture levels are generally higher, and in many riparian areas, soil nutrient levels are higher and the soil structure is better developed than in neighbouring upland areas. Many weed species are well adapted to take advantage of these conditions.

Floods impact on the invasibility of riparian areas in several ways. Weed propagules, both seeds and vegetative fragments, are distributed through the river corridor by floods. The erosion and subsequent deposition of sediment during floods create patches of bare ground which are suitable for the recruitment of weed species. Floods also remove existing vegetation, decreasing competition for resources such as nutrients and light.

The frequent disturbance caused by floods makes riparian vegetation communities more susceptible to invasion by pioneer species, including many weed species, than surrounding, less disturbed communities. The additional impacts of human activities have increased the frequency and likelihood of disturbance in riparian areas, and consequently weed establishment. These activities include changes in hydrological regimes, land clearing, use of riparian areas for agricultural production including stock grazing, and recreation. Humans also facilitate the dispersal of weed propagules, either deliberately or inadvertently, and thus increase the weed pressure on riparian areas.

Summary point

Features of riparian areas, particularly floods, make these parts of the landscape more susceptible to weed invasion than other areas.

Species found in riparian areas

In most riparian areas, multiple weed species are present in varying levels. These range from herbaceous ground covers and grass species, through to shrubs and trees. Few of these species can be regarded as riparian specialists; most are present more widely in the landscape, although they may be more common in riparian areas.

A list of weeds commonly found in riparian areas in south-eastern Australia, particularly Victoria, and their natural dispersal mechanisms is given in Appendix 1.

Thistles are ubiquitous in the landscape, but are unlikely to transform habitat. Photo: Trevor Hunt DPI Victoria

Impacts of weeds in riparian areas

Weeds displace native species and in riparian areas this affects both the biological and physical processes in the ecosystem.

Different weed species have different impacts. Transformer species, eg broom, blackberries, tree willows and shrub willows, often form dense infestations that have significant impacts on many ecosystem processes. Scrambling species that can climb up mature trees have the potential to severely affect the growth and health of native vegetation (eg Cape ivy and English ivy). In contrast, other species such as some flatweeds and Yorkshire fog grass, although common in riparian areas, rarely form dense infestations and generally appear to have relatively little impact on either biological or physical processes.

Weeds in riparian areas may:

- change vegetation community composition
- inhibit recruitment and growth of native plant species
- decrease food and habitat for native fauna, both terrestrial and aquatic
- change aquatic food webs
- provide food and habitat for exotic animals such as foxes and blackbirds
- change soil nutrient processes
- decrease water quality
- change sedimentation, erosion and hydrological processes
- decrease water quantity (eg willows)
- change water temperature and light conditions by overshading the waterway
- reduce access and recreational opportunities.

It should be noted that much evidence about the impacts of weeds on these processes is based on anecdotal observation, rather than on scientific analysis which has been limited. However, in some instances such analysis does support commonly held assumptions. For example, recent (as yet unpublished) studies by scientists at the Commonwealth Science and Industrial Research Organisation (CSIRO) have demonstrated that willows do use more water than native river red gums in equivalent circumstances, thus validating assumptions that willows can have a negative impact on water quantity.

In contrast, it is widely believed that many weeds reduce the recruitment of native riparian tree and shrub species. This assumption was not supported by a recent Cooperative Research Centre for Australian Weed Management (Weeds CRC) research project assessing riparian vegetation in Victoria. This project found that on a landscape scale, there was considerable co-occurrence of native tree seedlings with high weed densities at some study sites. At these sites, it is possible that flood events created bare patches which were exploited as recruitment opportunities both by native tree seedlings and weeds.

Summary point

Weeds can have a number of impacts within riparian areas, but it is important to assess the likely impacts at a particular site rather than making assumptions based on generalisations.

Infestation of caper spurge on the upper Ovens River, north-east Victoria.
Photo: Trevor Hunt DPI Victoria

Blackberry thickets can reduce recreational access to rivers.
Photo: Trevor Hunt DPI Victoria

Methods of weed spread

The extent to which a riparian area is invaded by particular weed species depends on both the characteristics of the riparian environment and the proximity of weed propagules. Weeds can move through the landscape via seeds or from vegetative propagules such as stem and root fragments, bulbs, corms and rhizomes, which have the potential to form new plants under suitable conditions.

Seeds may be dispersed by wind, water, animals and / or explosive mechanisms. Many riparian weeds are wind- or water-dispersed, which allows them to travel long distances across the landscape. Animals and birds can also disperse seeds long distances, either by distributing seeds after consuming fruit or by inadvertently transporting seeds on their coats or feathers. This long-distance dispersal ability of weed seeds, coupled with the fact that many weed species are relatively common in the landscape, makes it difficult to prevent the occurrence of these weeds in riparian areas.

Legume species such as gorse and broom often disperse their seeds over short distances by the explosion of ripe pods, which fling the seeds several metres from the parent plant.

For some riparian weed species, vegetative propagation is the dominant means of reproduction. Stem fragments of crack willow, tradescantia and blue periwinkle are very effective at colonising new sites and producing dense infestations. These fragments are carried long distances by water, particularly in floods, and dispersed across shorter distances by localised disturbance events. Other species propagate using specialised structures. For example montbretia produces corms while angled onion produces bulbs. These structures enable these plants to disperse over short and long distances via water and human activities.

Willow seeds ripe for dispersal.
Photo: Trevor Hunt DPI Victoria

A number of riparian weed species reproduce by both seed and vegetative propagules; examples include Cape ivy and English ivy.

Human activities such as clearing vegetation, slashing or mowing, movement of vehicles and dumping of garden waste can also assist in the dispersal of weed seeds and vegetative propagules.

Given the variety of dispersal mechanisms over both short and long distances, maintaining weed-free riparian areas is a very difficult proposition. The number of weed propagules reaching the riparian zone will be primarily dependent on the weed populations in adjacent land areas and in upstream areas, but weeds present further afield also have the potential to invade riparian areas.

Summary point

Riparian weeds reproduce either by seed or vegetative propagules, which can be widely dispersed via wind, water, animals or human activities.

Weeds and floods

Flood events are the key natural disturbance events in riparian areas and occur with varying frequencies and intensities. Some river systems experience floods several times a year, while other systems flood much less often.

Flood events influence the weed populations in riparian areas by:

- moving seeds and vegetative propagules along the river corridor
- moving sediment—eroding it from some sites and depositing it at others
- removing existing vegetation and thus creating recruitment sites free of competition.

These newly created recruitment sites of bare sediment, free of competing vegetation, can provide establishment sites for weeds or native species. It is important therefore, to understand whether or not regeneration processes of key native species are strongly tied to flood events. If so, post-flood weed management activities need to be undertaken with extreme care to prevent damage to native seedlings. In riparian areas where post-flood native regeneration is important but lack of seed is limiting, flood events may provide the ideal opportunities to undertake direct seeding or planting.

2. Weeds in riparian areas

The hydrological regimes of many river systems have been significantly altered by human activities. In some rivers, this has resulted in a change in seasonality of high and low flows, while in other systems changes in hydrological regimes have resulted in fewer, less severe flood events. These changes affect all aspects of the riparian system and may increase the likelihood of weed invasion.

For highly regulated rivers where large volumes of water are diverted for other purposes, reductions in flow and changes in the location of river channels can result in areas that were formerly riparian becoming disconnected from the aquatic component of the system. In other river systems, low flows as a result of diversions or prolonged drought expose previously inundated substrate and these areas can become new sites for weed establishment. For example, in some rivers in north-east Victoria, it is likely that the recent drought and consequent low flows has provided new recruitment sites for some willow species.

In addition, it is likely that climate change will have significant consequences for hydrological regimes in south-eastern Australia. Current predictions indicate that temperatures will increase and rainfall will decrease, resulting in lower flows into waterways. There may also be changes in the seasonality of rainfall. One of the most important factors affecting riparian areas relates to the expectation that climate change will result in an increase in severe weather events, particularly intense rainstorms. These are likely to result in severe floods which will cause significant disturbance in riparian areas.

Other disturbance factors that can influence weed invasion in riparian areas include the activities of animals such as deer, pigs and lyrebirds which wallow or turn over large areas of ground, disturbing vegetation and creating bare patches. Fires are also important disturbance factors that create recruitment opportunities. Intense fires that remove much of the existing vegetation result in large areas of bare sediment that can be readily transported through the river corridor in subsequent floods, exacerbating the disturbance processes associated with floods.

Summary point

Floods are the key natural disturbance events in riparian areas and provide potential recruitment opportunities for weeds and for native species. Floods move weed propagules through the river corridor. Changes in hydrology can increase the likelihood of riparian weed establishment.

Blue periwinkle can form dense mats of herbaceous vegetation in riparian areas. Stem fragments of blue periwinkle are dispersed over long distances via flood events.
Photos: Trevor Hunt DPI Victoria

Low flows can provide new sites for weed invasion.
Photo: Fiona Ede DPI Victoria

Case study: reproduction and dispersal in willows

In much of south-eastern Australia, willows (*Salix* spp.) are serious weeds of waterways and wetlands, due to their highly invasive nature and detrimental impacts on river health. These impacts include:

- the modification of stream channels and hence river flows
- exacerbation of riverbank erosion
- exclusion of native species from riparian vegetation communities
- changes in seasonality of litter inputs into streams which alters in-stream food webs
- alterations in water temperature and light environment
- reduction in water volumes due to increased water usage compared with native species
- reduction in access for recreational pursuits.

There are several different willow species and hybrids present in Australia, including both tree and shrub species. Being large, long-lived plants which can form extensive monocultures along waterways, willows often dominate riparian vegetation across large areas of the landscape. Much effort is currently expended on the removal of willows from riparian areas, with at least $10m invested annually in willow control in Victoria alone. A national willow management guide has recently been published to aid land managers in their willow management activities (Holland Clift and Davies 2007).

Many willow species are able to reproduce sexually and asexually. Asexual reproduction via stem fragments is common to many species, with crack willow (*S. fragilis*) the most notable example. These stem fragments can be transported downstream by river flow, and as they are able to readily establish in damp areas the weed spreads through the river corridor. Floods facilitate this process by snapping off fragments from parent trees during the high energy period of the flood, distributing the fragments along the river and by creating patches of bare ground suitable for the establishment of the fragments.

Reproduction by seed allows willows to spread widely across the landscape. It is a particular management problem with two species—black willow (*S. nigra*) and grey sallow (*S. cinerea*), but many other willow species are also capable of producing viable seed. Willow seed can be spread via water or wind. The seeds are very small and light, and can be blown several kilometres from the source, allowing invasion of new catchments. However, the seed only remains viable for 2–4 weeks, so there is no development of a seedbank. As well, the germination requirements of the seed are quite restrictive as the seed requires a light, open area of moist ground in order to establish.

Willows can dominate riparian areas and have significant impacts of ecosystem functions.
Photo: Trevor Hunt DPI Victoria

These requirements mean that willow seedlings can readily establish after a flood (or fire) event which has created bare patches of moist ground in the riparian areas. However, seedling establishment will only occur in the period immediately after seed shed, which occurs in spring. If bare ground is not colonised by willow seedlings at that time, it will not be colonised later in the season. Floods that occur in summer or autumn will not provide recruitment sites for willow seed shed the previous spring, but may provide sites for seed shed the following spring.

In riparian areas at risk from willow invasion, inspection of susceptible sites in the period following potential seedling establishment is important to prevent the development of new willow infestations from seed, while vigilance after floods at all times of the year is necessary to prevent stem fragments from becoming established. Removal of large willow trees is costly and can be difficult, whereas removal of rooted stem fragments is straightforward and low cost.

...case study

3. Weed management in riparian areas

Context

Weed management is one component of overall habitat management in riparian areas, and thus the objectives and techniques of weed management will vary between sites. For many riparian areas, the overall management objective is to improve some aspect or aspects of ecosystem functioning such as water quality, vegetation condition, regeneration capacity or habitat value. Often it is important to build resilience into the existing communities so they are better able to respond to disturbance.

In riparian areas surrounded by healthy native vegetation, weeds will often only constitute a relatively minor portion of the overall riparian vegetation community. In these areas, weed control is likely to be required at a low level and little other management intervention may be necessary to ensure the long-term health of the riparian community. At other sites, however, some level of ongoing management intervention will be required.

For those riparian areas that are no longer embedded in native-dominated landscapes, weed control may be a precursor to other management interventions such as an intensive replanting program, to rehabilitate riparian areas or to prevent further degradation.

In recent years large lengths of river frontage in productive areas have been fenced to exclude livestock. While this has had many benefits it should be noted that livestock may have been limiting the establishment of palatable weeds such as willows and grasses, and action may be required to manage these weeds after fencing-off.

Summary point

Weed management forms one part of overall habitat management.

Considerations

Potential sources of weeds need to be considered in the development of a riparian weed management program and may require activities to be undertaken in areas located away from the river corridor. For weed species which are primarily dispersed via water, initiating weed management in upper catchment areas is likely to provide a degree of weed control in the riparian area being managed and in riparian areas further downstream. However for weed species which disperse over long distances by other mechanisms, it is not safe to assume that weed management in upstream areas will provide adequate protection to areas downstream. Instead management may be better targeted at eliminating

Healthy riparian vegetation containing limited weeds along the Barham River, Otways, Victoria.
Photo: Trevor Hunt DPI Victoria

source populations elsewhere in the landscape or to increasing the resistance of the riparian area to invasion.

It is also important to understand whether a particular riparian weed infestation has the potential to become a source of weed propagules which could have serious implications for sites downstream. For example, much of the broom control undertaken in the headwaters of rivers in north-east Victoria is done more to protect off-site assets downstream from the infestation than for any immediate on-site benefits.

Weed control activities are not without risk and understanding the potential off-target impacts of weed management allows for a realistic assessment of the cost:benefit ratio. In some situations, any detrimental impacts on highly valued native communities may be unacceptable, while at other sites the potential impacts of the weed may be so severe that some limited off-target impacts may be deemed acceptable. In all situations, every effort should be made to reduce off-target impacts as much as possible.

In some riparian areas it is possible that some weed species are providing ecological benefits, for example through enhanced bank stability or by providing habitat or food for native species. It is important to understand these potential benefits so that if the management of these species is to be undertaken, measures are put in place to ensure these benefits are maintained.

Summary point

Understanding the sources of weeds, their potential off-site impacts and the benefits they may be providing to the riparian area are all important in designing a weed management program. The consequences of any potential off-target impacts of weed management also need to be carefully considered.

Multiple weed species

Due to the factors described earlier, riparian areas are often invaded by multiple weed species. Managing a diversity of weed species is complex, particularly in riparian areas with substantial native vegetation. A careful assessment of the impacts of the weeds present and of the values associated with the riparian area may sometimes lead to the conclusion that complete weed control is not a realistic option.

An alternative to attempting control of all weed species throughout the riparian area may be to only do the weed control that will provide a highly favourable outcome to protect or enhance values. For example, periodic weed control or control of particular species may be undertaken to protect threatened flora, to promote seed set and seedling establishment in native species or to allow public access. This may return large benefits without involving an attempt to produce a weed-free riparian zone. Such an approach may be particularly appropriate for riparian sites where it is not possible to prevent periodic reinfestation from upstream or inaccessible sources.

This approach also assists with setting priorities at sites where controlling weeds that are likely to have little or no impact on riparian functioning is given a lower priority than controlling those with high impacts.

As riparian areas are highly invasible, it is important to ensure that adequate attention is paid to anticipating the likely replacement species that will establish after weed management has been undertaken. Areas cleared of weeds remain vulnerable to reinvasion, either by the same species or other species. Particular attention should be paid to those weed species which are not controlled by the technique chosen to manage the dominant weed species at a site, as these species can potentially increase after management. In riparian sites with healthy native vegetation, native species may rapidly colonise managed areas but in many sites, ongoing weed management is necessary and replanting or seeding with native species may be required.

Summary point

As riparian areas often contain many weed species it is important to determine whether all species should be controlled, or whether management actions should focus on key weed species. It is also important to prevent re-invasion of areas which have been cleared of weeds.

Native seedlings and weeds often establish in close proximity, complicating weed management.
Photo: Trevor Hunt DPI Victoria

Timelines

In planning any weed management program, it is important to know the most appropriate time to undertake on-ground activities to optimise outcomes. Often this is influenced by the weed species being controlled or the control technique being employed. In riparian areas, the role of hydrology in weed management is an additional factor that requires consideration. Floods and water-logged soils may impede access, particularly for machinery, while periods of low flow can prevent boat access but facilitate access by foot.

For weed species which are spread by flood events, efforts to reduce source populations as much as possible should be undertaken between floods.

As flood events provide recruitment opportunities for weeds, regular post-flood monitoring of sites susceptible to weed invasion should be incorporated into short- to medium-term monitoring activities. This will ensure that weed control can be undertaken before weeds establish and reproduce at a site. This is particularly relevant to sites where upstream source populations are difficult to find or are inaccessible.

At sites where flood events often occur seasonally, the timing of weed management and monitoring activities can be planned to ensure the best outcome for investment in these activities.

Native species also exploit post-flood recruitment opportunities and so extreme caution is required in any post-flood weed control operations to prevent damage to native seedlings. It may be better to defer weed management until such time as native recruits can easily be identified and protected from weed control activities. Regular post-flood monitoring will assist in determining the best time to undertake weed control.

In rare situations, weed management in riparian areas can achieve the desired outcomes within a short time frame. It is more usual, however, that a long-term commitment is required to achieve adequate weed control. This will involve repeated site visits to monitor the efficacy of management activities and to determine the most appropriate actions as the management program progresses. Initial control by application of herbicides for example, may need to be followed up with additional applications or with hand removal of new seedlings or individuals not controlled by the herbicide. In many situations, guaranteed resourcing for long-term weed management activities is not available, and this may limit the range of activities which can be undertaken. However, a lack of long-term resourcing should not prevent weed management being undertaken in riparian areas, particularly at sites where significant short-term gains can be made through weed control.

Management options

The most appropriate weed management options for a riparian area will be determined by the objectives for the site, features of the site including access, the weed species present and resource capacity. Management guides for a limited number of riparian weed species are available on the Weeds CRC website listed in the 'Further reading' section.

As with all weed management programs, options that provide the best control while causing the least amount of disturbance are preferred to minimise the likelihood of further weed invasion.

Physical control

Mechanical and physical strategies can be applied in riparian areas in some circumstances. For example, many willow management activities involve the use of large machinery to cut down and clear willow trees from riparian areas. However, in areas with high levels of native vegetation or in sites with cultural significance, use of machinery is inappropriate. In some areas, wet soils or steep terrain prevent machinery access, and in other sites machinery can significantly damage soils and affect bank stability.

In the early stages of an infestation, hand-pulling may be sufficient to remove the weeds from a site. In areas with high levels of native vegetation and relatively few weeds, manual removal is often the best management option.

Physical removal of trees in riparian areas presents many challenges and is only appropriate in some situations.
Photo: Trevor Hunt

Chemical control

There are a limited number of herbicides registered for use around waterways due to the requirement to minimise impacts on water quality, hence chemical control options in riparian areas are restricted. Prior to undertaking any chemical control in riparian areas, it is advisable to consult the appropriate state or territory agency responsible for the administration of herbicide use.

All herbicide use must be in accordance with the instructions on the label and with any permits that have been obtained.

Herbicides may be applied in a number of ways (see Table 1) with different application techniques appropriate to different situations. For example drill and fill or cut and paint techniques do not have the risk associated with spray drift of foliar herbicide applications.

Biological control

Biological control (biocontrol) programs are effective for some weed species, but the multiplicity of weed species in riparian areas means biocontrol can only form a small component of a weed management strategy.

Biocontrol may be effective in controlling inaccessible populations, where other control measures are unavailable.

There are situations where biocontrol can significantly decrease the population of the dominant riparian weed, for example if the blackberry taxa present are susceptible to the blackberry rust fungus. However, it must be ensured that the decline of the dominant weed species at these sites, through the action of biocontrol agents, does not result in an increase in levels of other weed species.

Table 1: Weed management techniques

Management options	Applicable situations
Hand-pulling, manual removal	Small infestations Early stage infestations Sites with predominantly native vegetation Species not effectively controlled with available chemicals
Physical control (machinery)	Predominantly exotic vegetation Multiple weed species No limitations to access
Chemical control: – foliar spraying – cut and paint – drill and fill – frill and fill	Large infestations Multiple weed species or monocultures Sites with either predominantly exotic vegetation or a mixture of native and exotic vegetation Sites which may have access limitations
Biological control	Only available for limited number of weed species May be particularly important for sites not readily accessible for other control options
Revegetation with native species	Sites where additional native plants are desired May be through planting tube stock or direct seeding

4. Planning riparian weed management programs

Planning outline

The steps outlined here focus on the weed component of an overall management program but many of the questions posed are relevant to the development of any land management program.

Consultation with all stakeholders is integral to the planning process, and the development of partnerships will improve the likelihood of long-term success. These stakeholders include landholders, local community groups, indigenous groups, recreation groups, appropriate state and local government agencies, and water and catchment management authorities. In some instances, engaging the community in riparian management can be facilitated by demonstrating the benefits of undertaking management at highly visible sites which act as case studies.

Any weed management program should be well planned, regardless of where in the landscape the management activities will occur. Several steps are required which are listed below and outlined in Figures 1 and 2.

Although the planning process appears linear, an adaptive management approach ('learning by doing') will be most effective. Thus integrating information gained from one part of the process into other parts allows for ongoing improvement of the program. This is particularly relevant for the data collected during the monitoring and evaluation phase, which should be used to inform the assessment of feasibility of threat control and in determining management objectives and the most appropriate control options.

The information gained from monitoring should also be integrated into the development of new weed management programs.

Riparian grassy woodland along the lower Ovens River, north-east Victoria.
Photo: Fiona Ede DPI Victoria

Phase 1—Strategic planning

1) Identify the assets in the system being managed:

- What assets will management activities protect or enhance?
- What are the physical, biological and cultural values of these assets? These may include threatened species, communities of value, water quality or stable banks.
- Are there off-site assets that require protection?

2) Identify and assess the threats posed to those assets:

- What factors pose a threat to the assets and their values?
- Do weeds pose a threat?
- What are the relative risks posed by each threat—are some threats a higher priority for management than others?
- Which threats require management?
- Is the riparian area so affected by changes in the landscape that weeds are a relatively minor contributor to decreased riparian health?

3) Identify the feasibility of managing each threat:

- Is it possible to manage all the threats?
- Do the management strategies for the different threats affect one another, such that the success of mitigating one threat relies on success in managing another threat?
- Will managing all the threats at this site result in an acceptable benefit for the required investment?

For **weeds**, assess the feasibility of management by determining:

- the weed species currently present and those that could potentially invade
- the sources of the weeds and their means of reproduction and dispersal
- the impacts of the weeds
- the extent and condition of existing native vegetation
- factors that influence site invasibility, including surrounding land use
- whether access will limit control options.

4) Determine the management objectives:

- What overall outcomes are all the site management activities seeking to achieve?
- Why is weed management being undertaken?
- What long-term outcomes is the weed management seeking to achieve?
- Do data collected from monitoring previous management activities (Fig. 2) inform the development of management objectives?

Addressing these steps will require an assessment of the landscape context of the riparian area to be managed. In some catchments, weeds in riparian areas may be a symptom of wider catchment management issues, and these threats will need to be addressed before any weed control will be successful. These potential threats include significant changes in hydrological regimes including decreased water flow through the system due to dams and other impoundments and off-takes, and changes in flood regimes. Increases in nutrient levels due to run-off from fertiliser applications on adjacent productive land and grazing by domestic stock can also promote weed growth in riparian areas. Increased disturbance through land clearing or fire will increase the susceptibility of riparian areas to weed invasion.

Where these factors, particularly irreversible changes in hydrology, have significantly changed features within the riparian system it may not be possible to restore the original riparian vegetation. At these sites, weed management may be undertaken to establish or protect riparian vegetation dominated by desirable species, and to contain weeds that pose a high risk to other areas.

If the surrounding area is in good ecological health, with healthy native vegetation communities adjoining the riparian area and the hydrology of the river system is relatively natural, then there is a high likelihood of a well-designed weed management program succeeding in reducing weed impacts. However, if the vegetation on adjacent land is predominantly exotic (eg in agricultural, urban or peri-urban areas) then maintaining an acceptable level of weeds in the riparian area will be extremely difficult. In these situations, the narrow extent of the native vegetation corridor and thus the high edge:area ratio results in a high probability of reinvasion by weeds along the edges of the corridor.

By undertaking steps 1—4 of the strategic plan, it will be possible to determine if a riparian weed management program is appropriate. If it is, then these same steps can be used to assist in prioritising sites for weed management. Once these decisions have been made, the operational details of the weed management program can then be developed.

Phase 2—Operational planning

The following steps are all required in planning an on-ground weed management program, however this list is non-hierarchical and the order in which the steps are addressed will vary between programs.

Identify all the resources required over the lifetime of the program:

- Labour, materials, chemicals, machinery.
- For how long can the program be supported—if ongoing maintenance cannot be guaranteed is it possible to achieve self-sustaining changes that will have ongoing benefits?

Determine most appropriate weed control options:

- What available method/s will maximise effectiveness of control but minimise risks to off-target vegetation, soil and water?
- What control method/s is/are most appropriate for the site, based on physical characteristics and the weed species present?
- What control methods are appropriate at different phases of the management program?

Identify site characteristics that will impact on weed management activities:

- Does the flood regime of the river affect any aspect of management effectiveness, such as timing of activities or choice of control methods?
- Are there any problems with site access?
- Does the land use or vegetation of the surrounding land affect management options?

Determine the most suitable timing of operations:

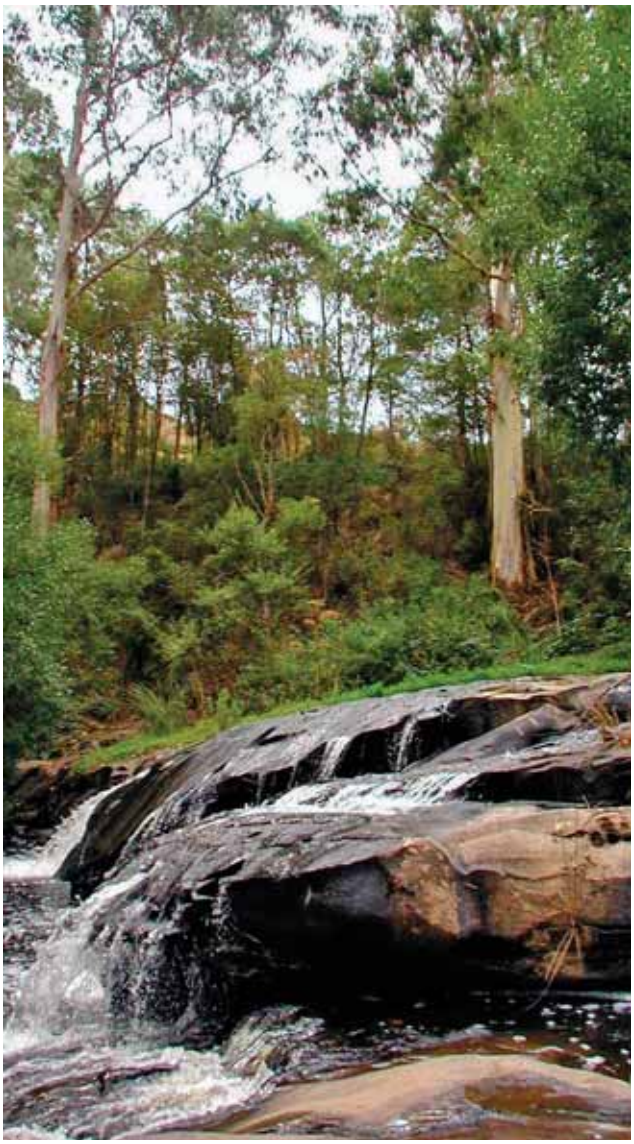
- Is access likely to be limited by soil moisture or river levels at certain times of the year?
- At what time of year will the weed control method/s be most effective?
- How often will management activities need to be undertaken at the site to control both emerging and established plants?
- Is there a series of activities that needs to occur in sequence to ensure success?
- Do flood events influence the timing of weed management or monitoring activities?

Develop and implement a consultation strategy with all relevant parties:

- Have all parties been consulted about the weed management program?
- Are partnerships in place to maximise the success of program outcomes?
- Have required permits been obtained?

Develop a long term monitoring and evaluation process:

- How will the success of the weed control program be evaluated, in relation to improving environmental outcomes and providing a good return on investment?
- What factors will be monitored to determine the effectiveness of the weed control program over the short, medium and long term?
- Who will undertake the monitoring and evaluation and how will it be paid for?
- How will the information collected during the monitoring process be incorporated into the ongoing weed management program to adapt it over time?
- How will any lessons learnt through undertaking the weed control program be communicated to other interested parties and incorporated into the development of future weed management programs?



Franklin River, Gippsland, Victoria.
Photo: Michelle Jones-Lennon DPI Victoria

Figure 1 Strategic plan

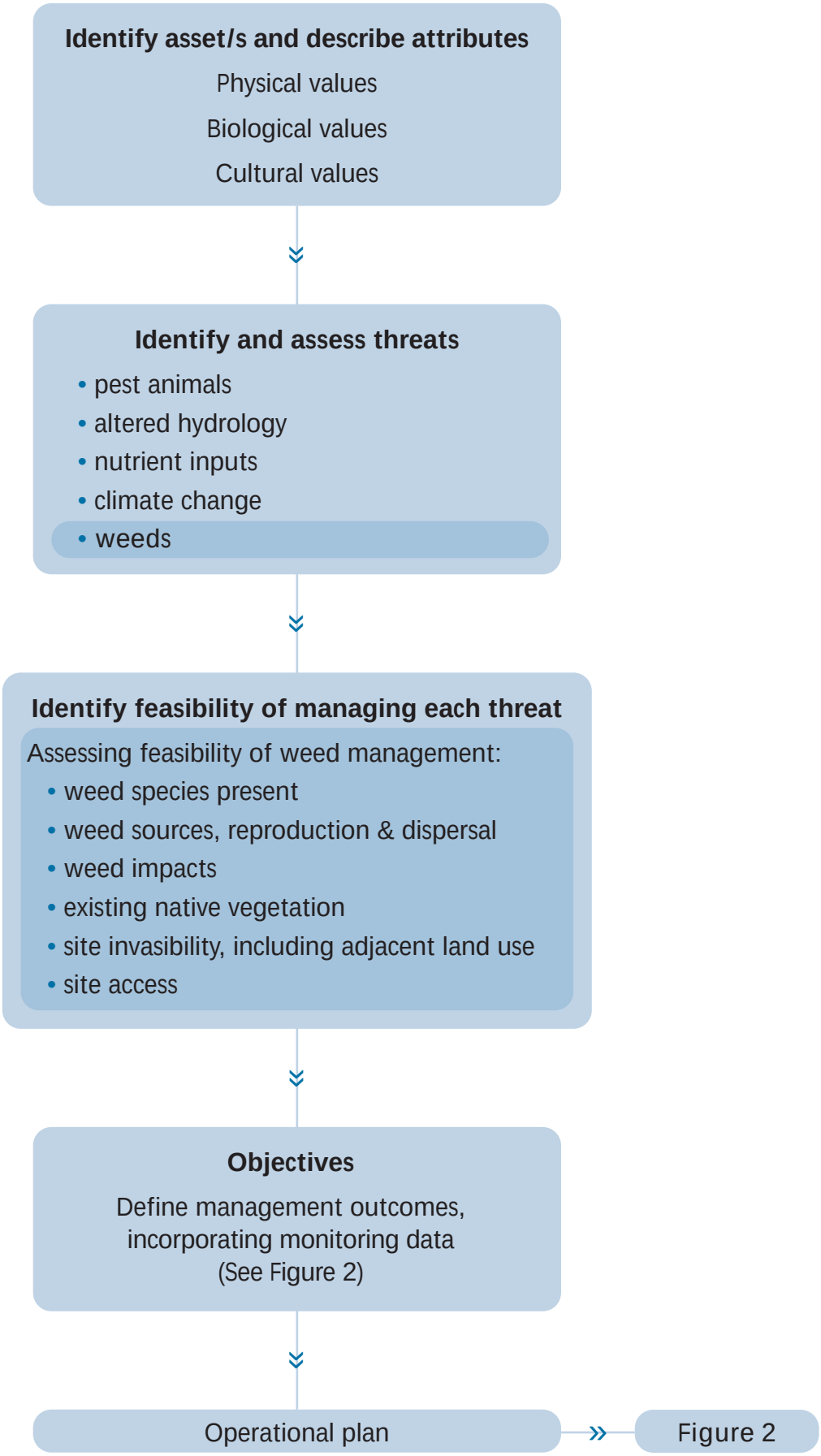
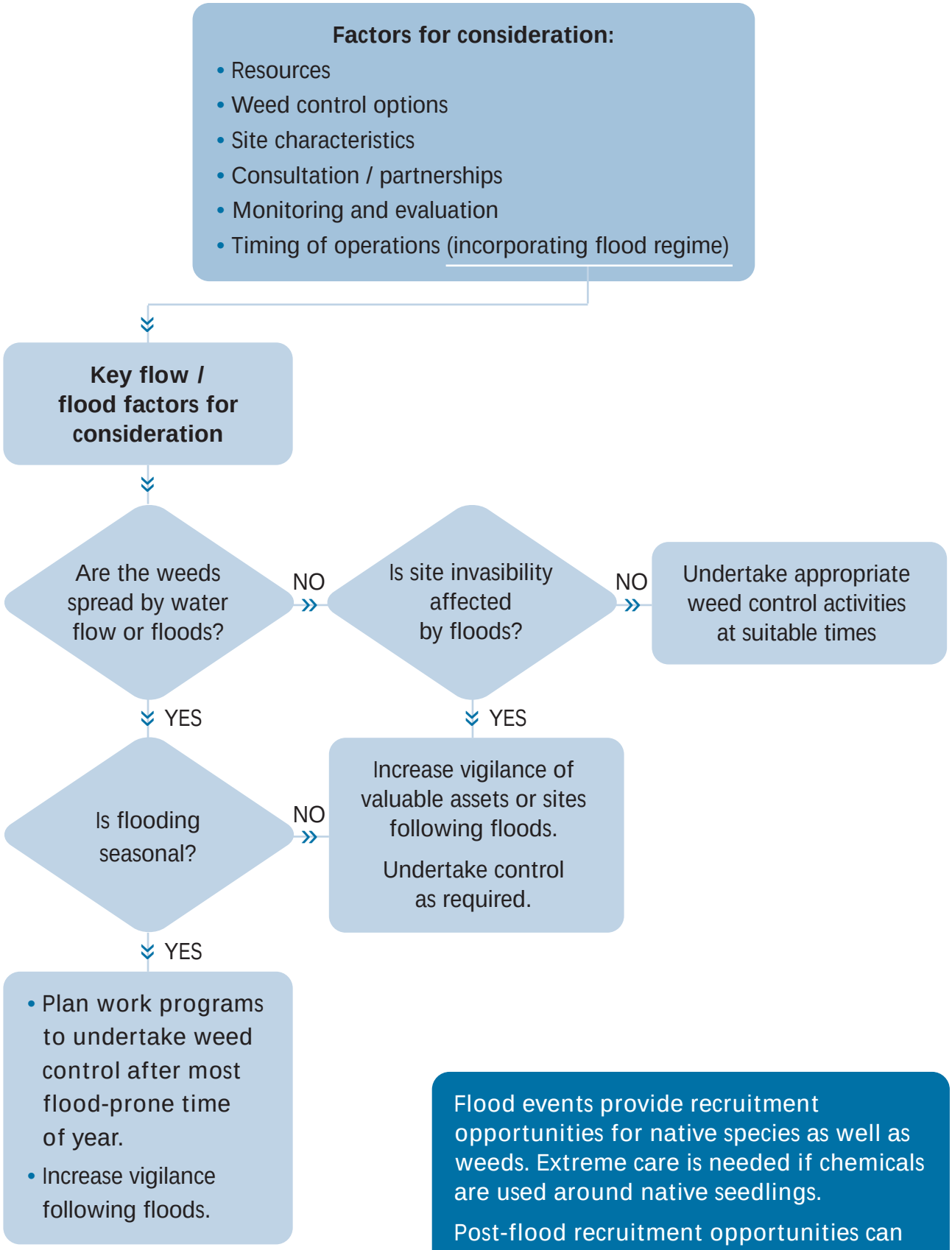


Figure 2 Operational plan



Conclusion

An asset-based approach to planning riparian weed management programs takes into account the landscape context and the complexities of managing weeds in this important part of the environment. Integrating new information into riparian weed management programs, through adaptive management, allows for the ongoing improvement of these programs.

- Managing weeds in riparian areas is indeed one of the most difficult challenges for land managers, because riparian areas are inherently invasible and control options are limited.
- Effective weed management programs require sound planning and a significant investment of resources over many years to be truly effective.
- Understanding the physical characteristics of the riparian system is important, including the hydrology and relationships with other parts of the landscape.
- Knowledge of the sources, dispersal mechanisms and impacts of weeds in the riparian area is also required.
- A well planned and executed riparian weed management program can result in significant benefits to both the physical and biological components of the river corridor.

Riparian areas provide environmental and social benefits. St Georges River, Otways, Victoria.
Photo: Fiona Ede DPI Victoria

Further reading

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Appendix 1

Weeds common in riparian areas in south-eastern Australia, particularly Victoria, and their natural dispersal mechanisms

Habit	Common name	Scientific name	Dispersal mechanisms[1]
Grass / bulb	African feathergrass	*Pennisetum macrourum*	Aa; Wa; Wi
	angled onion	*Allium triquetrum*	Wa; Wf
	cocksfoot	*Dactylis glomerata*	Aa: Wa
	cumbungee	*Typha latifolia*	Wa; Wf; Wi
	kikuyu	*Pennisetum clandestinum*	Wf
	montbretia	*Crocosmia* x *crocosmiiflora*	Wa; Wf
	phalaris	*Phalaris aquatica*; *P. arundinacea*	Aa: Wa
	rice cut-grass	*Leersia oryzoides*	Wa
	ryegrass	*Lolium* spp.	Aa; Ai; Wa; Wi
	spiny rush	*Juncus acutus*	Aa; Wa
	water couch	*Paspalum distichum*	Aa; Wa
	yellow flag iris	*Iris psuedocorus*	Wa; Wf
	Yorkshire fog	*Holcus lanatus*	Aa: Wa
Herbaceous	blue periwinkle	*Vinca major*	Wf
	buttercup	*Ranunculus repens*	Wa
	caper spurge	*Euphorbia lathyrus*	Wa
	cleavers	*Galium aparine*	Aa; Wa
	dock	*Rumex* spp.	Wa
	lippia	*Phyla canescens*	Wf
	mint	*Mentha* spp.	Wa; Wf
	soursob	*Oxalis* spp.	Wa; Wf
	St Johns wort	*Hypericum perforatum*	Aa; Wa; Wi
	thistle	eg *Carduus* spp.; *Cirsium* spp.; *Onopordum* spp.; *Silybum* spp.	Aa; Wa; Wi
	tradescantia	*Tradescantia fluminensis*	Wf
Shrub	African boxthorn	*Lycium ferocissimum*	Ai
	blackberry	*Rubus fruticosus* agg.	Ai
	Cape / Montpellier broom	*Genista monspessulana*	Ex; Wa
	cestrum	*Cestrum parqui*; *C. elegans*	Ai; Wa
	English broom	*Cytisus scoparius*	Ex; Wa
	gorse	*Ulex europaeus*	Ex; Wa
	grey sallow	*Salix cinerea*	Wa; Wi
	hawthorn	*Crataegus monogyna*	Ai; Wa
	Himalayan honeysuckle	*Leycesteria formosa*	Ai
	karamu	*Coprosma robusta*	Ai
	mirror bush	*Coprosma repens*	Ai
	sweet pittosporum[2]	*Pittosporum undulatum*	Ai
	tutsan	*Hypericum androsaemum*	Ai; Wa
Tree	box elder	*Acer negundo*	Wa; Wf; Wi
	desert ash	*Fraxinus angustifolia* ssp. *angustifolia*	Wa; Wf; Wi
	holly	*Ilex aquifolium*	Ai
	olive	*Olea europaea* ssp. *europaea*	Ai
	peppercorn tree	*Schinus molle*; *S. terebinthifolius*	Ai
	poplar	*Populus* spp.	Wa; Wi
	sycamore maple	*Acer pseudoplatanus*	Wa; Wf; Wi
	tamarix, Athel pine	*Tamarix aphylla*	Wa
	tree of heaven	*Ailanthus altissima*	Ai; Wa; Wi
	willow eg black willow eg crack willow	*Salix* spp. *Salix nigra* *Salix fragilis*; *S.* x *rubens*	Wa; Wf; Wi Wa; Wi Wa; Wf
Vine / climber	Cape ivy	*Delairea odorata*	Aa; Wa; Wi
	English ivy	*Hedera helix*	Ai
	Japanese honeysuckle	*Lonicera japonica*	Ai

[1] Ai = animal internal; Aa = animal attached; Ex = explosive pod; Wa = water; Wf = water (flood); Wi = wind

[2] *Pittosporum undulatum* is weedy in parts of Victoria and indigenous elsewhere

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