A guide to managing and restoring wetlands in Western Australia

Wetland weeds

Chapter 3: **Managing wetlands**

Version 1

Australian Government

Department of Environment and Conservation

Our environment, our future

Introduction to the guide

Western Australia's unique and diverse wetlands are rich in ecological and cultural values and form an integral part of the natural environment of the state. *A guide to managing and restoring wetlands in Western Australia* (the guide) provides information about the nature of WA's wetlands, and practical guidance on how to manage and restore them for nature conservation.

The focus of the guide is natural 'standing' wetlands that retain conservation value. Wetlands not addressed in this guide include waterways, estuaries, tidal and artificial wetlands.

The guide consists of multiple topics within five chapters. These topics are available in PDF format free of charge from the Western Australian Department of Environment and Conservation (DEC) website at www.dec.wa.gov.au/wetlandsguide.

The guide is a DEC initiative. Topics of the guide have predominantly been prepared by the department's Wetlands Section with input from reviewers and contributors from a wide range of fields and sectors. Through the guide and other initiatives, DEC seeks to assist individuals, groups and organisations to manage the state's wetlands for nature conservation.

The development of the guide has received funding from the Australian Government, the Government of Western Australia, DEC and the Department of Planning. It has received the support of the Western Australian Wetlands Coordinating Committee, the state's peak wetland conservation policy coordinating body.

For more information about the guide, including scope, purpose and target audience, please refer to the topic 'Introduction to the guide'.

DEC welcomes your feedback and suggestions on the guide. A publication feedback form is available from the DEC website at www.dec.wa.gov.au/wetlandsguide.

Contents of the guide

These topics are available in PDF format free of charge from the DEC website at www.dec.wa.gov.au/wetlandsguide.

'Wetland weeds' topic

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Photos from the publication *Western Weeds: a guide to the weeds of Western Australia* (2nd ed) have been reproduced with permission from the Weeds Society of Western Australia (Inc).

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When specific reference is made to this topic, the recommended reference is: Department of Environment and Conservation (2012). 'Wetland weeds', in *A guide to managing and restoring wetlands in Western Australia*, Prepared by T Bell, Department of Environment and Conservation, Perth, Western Australia.

Disclaimer

Contents

Case studies

Before you begin

Before embarking on management and restoration investigations and activities, you must consider and address the legal requirements, safety considerations, cultural issues and the complexity of the ecological processes which occur in wetlands to ensure that any proposed actions are legal, safe and appropriate. For more guidance, see the topic 'Introduction to the guide'.

Ecosystem services: the processes by which the environment produces resources that provide benefits to humans, e.g. flood and disease control, clean air, waste recycling, plant pollination[2]

Introduction

Weeds pose a serious threat to Western Australia's environment, society and the economy. Weeds threaten primary production, and the biodiversity and conservation values of Western Australian ecosystems.[1] They impact severely on agriculture and biodiversity by competing with crops and out-competing native plants and degrading habitat. The cost to Australian agriculture alone of managing weeds is estimated to be over $4 billion a year and in Western Australia, as much as 20 per cent of annual production costs.[2]

The cost of weeds from loss of biodiversity and **ecosystem services** is likely to be of a similar magnitude.[2] At present, environmental weeds are generally not managed to the same extent as agricultural or pastoral weeds.

In recognition of existing and potential impacts of weeds, in 2001 the Western Australian Government released *A Weed Plan for Western Australia*[1] to coordinate effective weed management across the state. The *State of the Environment Report: Western Australia 2007* further highlights the significance of weeds by identifying them as a number one priority for management.[2]

What is a weed?

In general terms, a **weed** can be defined as 'a plant that requires some form of action to reduce its harmful effects on the economy, the environment, human health and amenity, and [the term weed] can include plants from other countries or other regions in Australia or Western Australia.[2]

Naturalised: plants that spread and persist outside of their normal range of distribution

This topic focuses on '**environmental weeds**', which refers to plants that become established in natural ecosystems, altering natural processes and leading to the decline of the communities they invade.[3,1]

Where do weeds come from?

Most Western Australian weeds originate from South Africa, Europe, Asia and America, brought in by early settlers as ornamental garden plants or for aquaculture, pastoral and agricultural production.[4,5] It is estimated that about two thirds of the weeds now established in Australia originated from gardens[2] (see Figure 1). Some weeds were also introduced unintentionally transported in soil, in water and in animal fur and feed.

However, not all weeds originate from other countries. Some Australian native species have become **naturalised** outside their normal range of distribution and are considered weeds when they disrupt the structure and diversity of other native plant communities.

Figure 1. Native to South Africa, arum lily *(Zantedeschia aethiopica)* was first introduced as a garden plant and is still used in the floriculture industry. It is a major wetland weed that is very difficult to eradicate once established.
Photo – B Huston/DEC.

Weed distribution in Western Australia

About 10 per cent of Western Australia's flowering plants are introduced weeds and these comprise more than half of the recognised weeds in Australia. It is estimated that of the 1,233 identified weed species in WA, around 55 per cent are classified as environmental weeds, most of which (around 800 identified species) are found in the Swan Coastal Plain **bioregion** (see Figure 2).[2] Over 300 identified weed species occur in the South West region and between 100 and 200 identified species occur in parts of the Goldfields, Mid West, Pilbara and Kimberley regions. Weed numbers in the central desert area of WA is low in comparison, with less than 30 identified species.[2]

Bioregion: a territory defined by a combination of biological, social and geographic criteria rather than by geopolitical considerations; generally, a system of related, interconnected ecosystems[1]

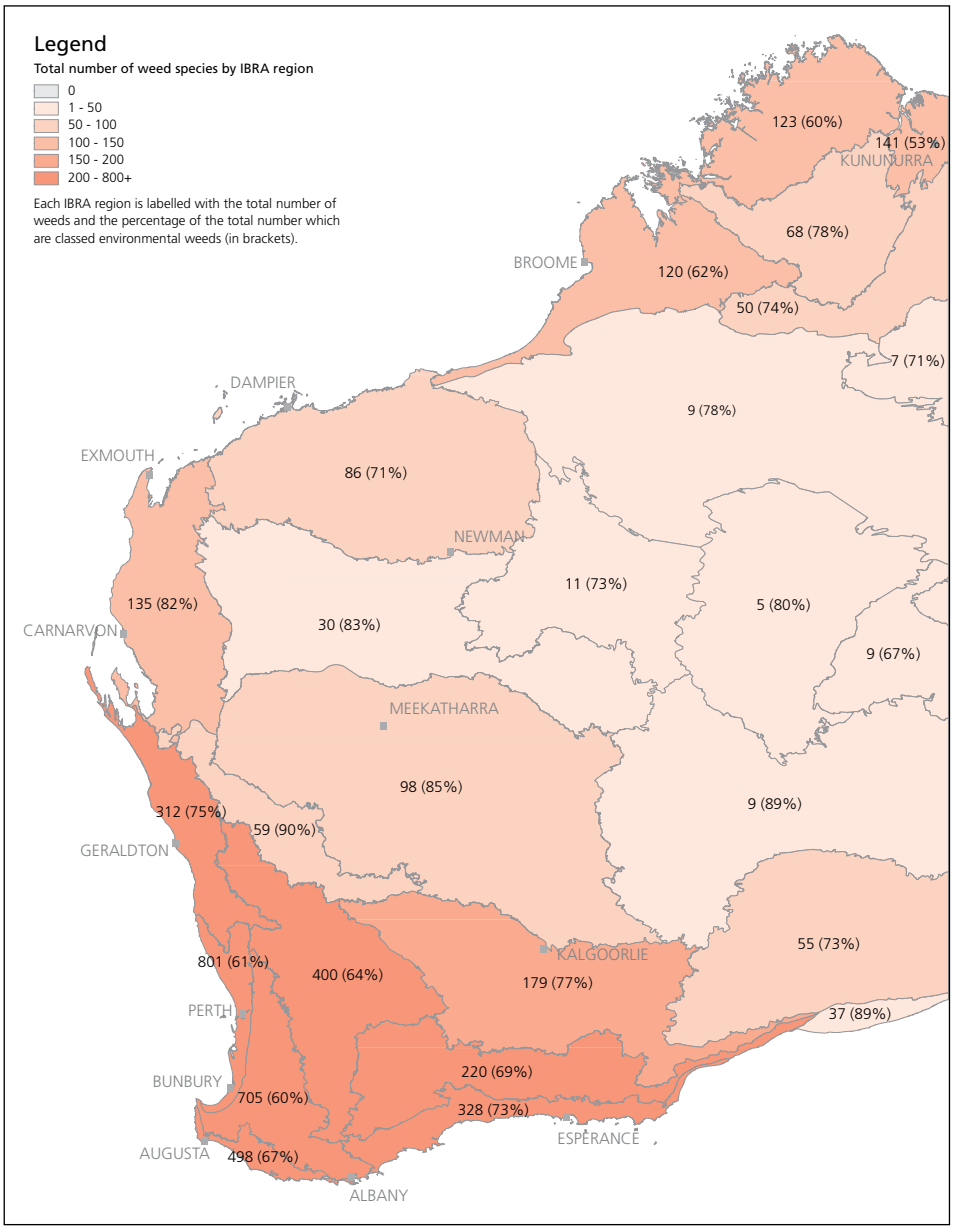


Figure 2. Total number of weed species found per bioregion and percentage that are environmental weeds (in brackets). Source: *State of the Environment Report: Western Australia 2007*.[2]

What causes weeds to occur and spread in wetlands?

In the south-west of Western Australia, weeds have invaded almost every wetland.[5] Weeds that flourish in wetlands often have broad tolerance limits to nutrients, pH, salinity and hydrological regimes and many are '**disturbance opportunists**', responding positively and rapidly to habitat disturbance. Understanding how weeds spread is essential in preventing them from becoming established in wetlands, and managing existing infestations.

Wetlands are vulnerable to weed invasion where there is disturbance of the soil and native vegetation, leaving the soil bare and ideal for germination of weed seeds. Disturbed edges of wetlands are most at risk from weed invasion, for example where they are located within or adjacent to highly disturbed landscapes such as housing settlements, parklands, paddocks, road verges and tracks.

When a wetland is disturbed, space and light conditions increase, creating favourable conditions for weed growth. Disturbance events in wetlands may be natural or resulting from human activities. Natural events in wetlands such as drying and wetting, drought and fire can lead to mass germination of many weed species.

Human activities that contribute to the introduction and spread of weeds include altering hydrology, clearing native vegetation, dumping garden waste, livestock access and vehicle movement (see Figure 3). Frequent fires and spread of dieback in urban wetlands and surrounding bushland also favour weed invasion and establishment.

Figure 3. (below) Weeds are introduced and spread around wetlands by many means including (a) dumping of garden waste such as prunings, lawn clippings and soil, (b) grazing livestock, and (c) vehicles in wetlands. Photos – T Bell/DEC.

(a)

Figure 3. (continued)

(b)

(c)

In comparison to disturbed areas, intact, undisturbed densely vegetated areas are more resilient to weed invasion as weeds are less able to get a foothold and compete for light, moisture and nutrients[5] (see Figure 4).

Figure 4. Wetlands with an intact understorey and few disturbances are more resilient to weed invasion. Photo – J Higbid/DEC.

Once established, weeds can very quickly dominate and degrade natural ecosystems by out-competing and replacing native plants, which may not be able to maintain their dominance or territory as a result (see Figure 5).

Figure 5. The understorey of this wetland has been completely replaced with kikuyu grass (*Pennisetum clandestinum*). Photo – T Bell/DEC.

Weeds can also occur in inundated areas of wetlands in which introduced aquatic plants can cover water surfaces and shade out submerged native aquatic plants and animals.[6] Aquatic weeds can be introduced into wetlands through disposal of ornamental aquatic plants from ponds or aquariums into wetlands or waterways and drains that feed into them (see Figure 6).

Seed dispersal mechanisms: the means by which plants distribute their seeds, for example via wind, water, birds and insects

The rate of weed invasion in wetlands depends on the type and level of disturbance(s) and the growth and reproductive characteristics of the weed. Other factors that influence weed invasion include climate, season, soil type, water and nutrient availability, extent, type and condition of native vegetation and presence of seed dispersal mechanisms.

Characteristics that give weeds a competitive advantage over many native species and assist in their spread include production of large numbers of highly viable seeds, multiple **seed dispersal mechanisms**, seed dormancy, underground storage organs and the ability to germinate and spread rapidly.[5] The absence of predators and diseases that would otherwise keep weeds in check in their countries of origin also provides a competitive advantage.[7]

Figure 6. Salvinia (*Salvinia molesta*) is a free-floating fern and a serious aquatic weed that forms dense masses on the water surface. It was originally introduced from South America as a pond ornamental. Photo – K Tripp/Shire of Wyndham East Kimberley.

Whilst many weeds are introduced to wetlands due to human activities, some invade by themselves through the dispersal of seed and vegetative propagules (see Figure 7). Weeds have a variety of adaptations that can help them disperse more effectively, such as sticky, hooked or light weight seeds that are ideal for catching a ride in fur, wool, clothing, wind or water. Some seeds are ingested by animals and birds and deposited in faeces in a different location.

Figure 7. Pasture grasses are common wetland weeds. Kikuyu grass (*Pennisetum clandestinum*) is spreading from this horse property across a firebreak into the vegetation of an adjacent wetland. Photo – T Bell/DEC.

Humans can assist in spreading weeds by transporting seeds attached to shoes, clothing or vehicles or by dumping soil fill (containing weed seeds or vegetative material), garden prunings or lawn clippings in and around wetlands. Wetland weeds generally produce large numbers of highly viable seed that are easily spread. For example, a major wetland weed, pampas grass (*Cortaderis selloana*), produces up to 100,000 seeds per flower plume, which are readily spread over long distances by wind and water[5] (see Figure 8). Bridal creeper, blackberry, olive tree and Japanese pepper have seeds encased in fleshy fruits that are rapidly dispersed by birds and foxes.[5]

Figure 8. Producing around 100,000 seeds per flower head, pampas grass (*Cortaderia selloana*) seeds are easily spread by wind and can travel for long distances. Photo – T Bell/DEC.

What effects do weeds have on wetlands?

Weed invasion poses a serious threat to the biodiversity and conservation values of wetlands and can disrupt key ecosystem functions.[5] The development of native seedlings can be hindered by the competition created by weeds for light, nutrients and moisture. This can lead to displacement of native plants and loss of biodiversity due to degradation and simplification of the wetland plant community. Weeds can also increase fire risk by increasing fuel loads in summer, contribute to soil erosion problems, reduce native fauna habitat and reduce overall ecosystem resilience[5] (see Figure 9).

Figure 9. Weeds can pose a serious fire risk in wetlands, particularly during summer when annual weeds die off, increasing fuel loads. Photo – Environmental Protection Branch/Fire and Emergency Services Authority.

Weeds can also contribute to reduction in water quality of wetlands, which in turn can lead to midge problems, algal blooms, loss of natural invertebrate communities, displacement of native species and a reduction in aesthetic and recreational values. Heritage values can also be affected by weeds, for example where traditional Aboriginal bush tucker plants are displaced or watering holes and camping sites are degraded.[5] The control of weeds is therefore essential for the long-term protection, management and restoration of wetlands.

Weed impact at a glance

The impact of environmental weeds on wetlands can be significant where they compete with native vegetation, inhibiting growth and natural regeneration. This can result in:

- loss of biodiversity as weeds replace native plants
- loss of habitat and food source for wetland birds and other fauna (e.g. replacement of native shrubs and groundcovers with grasses)
- increased fire risk
- increased erosion risk (e.g. bank erosion)
- altered nutrient recycling
- altered soil quality
- reduced water quality (e.g. reduction of light and oxygen from aquatic weeds)
- loss of aesthetic amenity and recreational value
- increased management costs.

The control of weeds is therefore essential for the long-term protection, management and restoration of wetlands.

Broadleaf: plants that possess relatively broad flat leaves rather than needle-like leaves

Succulent: plants which have specialised fleshy, soft and juicy tissues designed for the conservation of water e.g. cacti

What types of weeds affect wetlands?

To control wetland weeds successfully, it is vital to understand the different types of weeds that exist and how (and when) they grow, reproduce and spread. Without this knowledge, weed control measures may not be effective and may result in wasted time, money and effort. Inappropriate weed control may also result in direct or indirect damage to native flora and fauna and can exacerbate the weed problem.

Weeds can be divided into three broad types: non-woody weeds, woody weeds and aquatic weeds. Non-woody weeds are weeds with a non-woody green stem (i.e. are herbaceous), woody weeds have a woody stem and aquatic weeds are those that grow partly or wholly submerged in water.

Non-woody weeds

Non-woody weeds refer to weeds with a non-woody green stem. They include grasses, **broadleaf** herbs, rushes and sedges, **succulents**, ferns, some vines and plants that develop specialised underground storage organs known as bulbs, corms and tubers.

extra information

Weed life cycles and reproduction

Weeds have either an **annual**, **biennial** or **perennial** life cycle. Most wetland weeds are annual species, which means they normally complete their life cycle within a single growing season (from germination to flowering, seed production and death of vegetative parts). Biennial weeds normally complete their life cycle within two years while perennial weeds, often the most invasive type of weed, normally live for two or more growing seasons.

Weeds reproduce sexually through the production of seed, or asexually (or vegetatively), in which parts of the parent plant (e.g. spores, rhizomes, stolons, bulbs, tubers, corms and buds) detach and generate new individuals. Some weeds reproduce both sexually and asexually.

Life form: the shape or appearance of a plant that mostly reflects inherited or genetic influences

Grasses

Grasses can be one of the most serious and difficult weeds to control in wetlands. Once established, they can spread very quickly, smothering native vegetation, and in the case of many annual grasses (which die off during the summer months), significantly increasing wetland fuel loads and fire hazard. Many grasses are also extremely resilient and can re-sprout after damage from trampling, grazing, drought or fire.

Grasses are highly successful colonisers due to their specialised **life forms** and reproductive strategies. Understanding the growth and reproductive strategies of grass weeds is essential in order to identify the most appropriate control methods and how and when they are best applied.

Annual grasses

Completing their life cycle within a year, annual grasses produce seeds which can be dispersed very efficiently by one or more means including wind, water, native and domestic animals and vehicles. Individual plants may produce hundreds or thousands of seeds, which can remain dormant in the soil, waiting to germinate when conditions are favourable. Minimising soil disturbance, which exposes buried weed seeds, is a key strategy in controlling the germination and spread of annual weeds.

Fire can also trigger germination of dormant seeds, with the resulting bare soil and increased light and nutrient availability following a fire providing ideal conditions for grasses to become established.[5]

Examples of annual grass weeds that grow in wetlands include (see Figure 10):

- annual veldt grass (*Ehrharta longiflora*)
- barb grass (*Parapholis incurva*)
- fountain grass (*Pennisetum setaceum*)
- great brome (*Bromus diandrus*)
- blowfly grass (*Briza maxima*)
- rye grass (*Lolium* spp.)
- shivery grass (*Briza minor*)
- wild oat, bearded oat (*Avena fatua, A. barbata*).

Figure 10. (below) Examples of annual grass weeds that grow in wetlands. Photos – (a) and (b) R Randall/Western Weeds; (c) L Fontanini and KC Richardson; (d) A Ireland and KR Thiele; (e) L Fontanini; (f) J F Smith. Images (c)–(f) used with permission of the Western Australian Herbarium, Department of Environment and Conservation http://florabase.dec.wa.gov.au/help/copyright, accessed 6/11/2009.

(a) annual veldt grass (*Ehrharta longiflora*)

(b) bearded oat (*Avena barbata*)

(c) great brome (*Bromus diandrus*)

(d) blowfly grass (*Briza maxima*)

(e) shivery grass (*Briza minor*)

(f) annual barbgrass (*Polypogon monspeliensis*)

Perennial grasses

Vegetative reproduction: a type of asexual reproduction found in plants. It is also called vegetative propagation or vegetative multiplication

Perennial grasses can survive for several or more years, often producing highly viable seed each year that can be spread by wind, water, native and domestic animals and vehicles. Perennial grasses also reproduce **vegetatively** from **stolons**, **rhizomes** and occasionally corms, which store energy reserves that allow the plant to survive during dormancy or extreme conditions such as fire or drought. Stolons are stems that usually run horizontally along the soil surface and rhizomes are stems that are buried underground. Both types of stems have dormant buds that can produce new roots and shoots and allow rapid lateral (sideways) growth of plants, particularly after fire.[5] Perennial grasses are either summer or winter growing, forming tussocks or mats that can quickly smother native plants.

Examples of perennial grass weeds that grow in wetlands include (see Figure 11):

- African lovegrass (*Eragrostis curvula*)
- buffalo grass (*Stenotaphrum secundatum*)
- couch (*Cynodon dactylon*)
- kikuyu (*Pennisetum clandestinum*)
- paspalum (*Paspalum dilatatum*)
- perennial rye grass (*Lolium perenne*)
- perennial veldt grass (*Ehrharta calycina*)
- phalaris (*Phalaris aquatica*)
- sweet vernal grass (*Anthoxanthum odoratum*)
- tambookie grass (*Hyparrhenia hirta*)
- yorkshire fog (*Holcus lanatus*).

Tall (or giant) perennial grasses:

- African feather grass (*Pennisetum macrourum*)
- bamboo (*Bambusa* spp.)
- elephant grass (*Pennisetum purpureum*)
- fountain grass (*Pennisetum setaceum*)
- giant reed (*Arundo donax*)
- pampas grass (*Cortaderia selloana*).

Figure 11. (below) Perennial grass weeds that grow in wetlands. Photos – (a) JF Smith; (b) V English/DEC; Trevor Hall/DEEDI © The State of Queensland, Department of Employment, Economic Development and Innovation (Trevor Hall), 1995; (c) L Fontanini; (d) R Randall/ Western Weeds. Image (a) and (c) used with permission of the Western Australian Herbarium, Department of Environment and Conservation http://florabase.dec.wa.gov.au/help/copyright, accessed 6/11/2009.

(a) fountain grass (*Pennisetum setaceum*)

(b) buffel grass (*Cenchrus ciliaris*)

Figure 11. (continued)

(c) Yorkshire fog (*Holcus lanatus*)

(d) giant reed (*Arundo donax*).

Grass growth forms

Grasses fall into one of three descriptive growth forms; tussock, stoloniferous or rhizomatous. Understanding the different growth forms is a key consideration when deciding on the best control methods for specific weeds.

Tussock grasses

Tussock grasses are the most common grass growth form, usually forming dense, erect clumps that can create large fuel loads as they age and die off (see Figure 12). They reproduce by seed and/or by sprouting new shoots located at the base of the plant. Most annual grasses are tussock forming, such as annual veldt grass (*Ehrharta longiflora*), fountain grass (*Pennisetum setaceum*) and wild oat (*Avena fatua*). Examples of perennial tussock grasses that can occur in wetlands include pampas grass (*Cortaderia selloana*), perennial veldt grass (*Ehrharta calycina*) and tambookie grass (*Hyparrhenia hirta*).

Figure 12. Example of a tussock grass (perennial veldt grass, *Ehrharta calycina*). Photo – R Cousens/Western Weeds.

Stoloniferous grasses

These grasses possess specialised stems called stolons that store energy reserves and spread laterally across the soil surface, sprouting new shoots and roots. Stoloniferous grasses also produce seed, which in combination with reproduction by runners, makes them extremely invasive, particularly where moist, fertile soils are present. Examples of species that can occur in wetlands include kikuyu (*Pennisetum clandestinum*), couch (*Cynodon dactylon*) and saltwater couch (*Paspalum vaginatum*).

Rhizomatous grasses

Rhizomatous grasses spread laterally by means of special underground stems called rhizomes, which sprout new roots and shoots as they grow. Like stoloniferous grasses, rhizomatous grasses can also reproduce by seed, making them extremely invasive. Rhizomes store energy reserves and being underground, they are protected from extremes in climate (e.g. during drought or fire), allowing them to re-sprout vigorously if the above ground portion of the plant is damaged or killed. They are highly invasive, particularly where moist, fertile soils are present. Examples of species that can occur in wetlands include giant reed (*Arundo donax*), perennial veldt grass (*Ehrharta calycina*) and kikuyu (*Pennisetum clandestinum*). Some grasses, such as kikuyu, produce both rhizomes and stolons.

extra information

Native grasses that look like weeds

Western Australia has many species of native plants that can be mistaken for weeds. Native grasses are particularly prone to mistaken identity (see Figure 13). For this reason, it is essential to accurately identify weed species before implementing a weed control program.

(a)

(b)

Figure 13. The weed tambookie grass (a) (*Hyparrhenia hirta*) is sometimes mistaken for native kangaroo grass (b) (*Themeda triandra*). Photos – P Hussey/Western Weeds.

➤ For additional detail on weed identification see the section 'Sources of more information on managing weeds in wetlands' at the end of this topic.

Broadleaf herbs

As with grass weeds, it is important to distinguish between annual and perennial herbs as this helps to determine the most appropriate management and control strategy.

Annual herbs

Most annual herbs in south-western Australia germinate with the first rains of autumn and set seed and die during the following summer months.[8] However, in wetlands, some annual weeds germinate when water levels drop during spring and set seed the following autumn. Other species are more opportunistic, sometimes germinating, flowering and setting seed more than once a year when conditions are favourable.[8] Examples of common annual herbs that can occur in wetlands include (see Figure 14):

- blackberry nightshade (*Solanum nigrum*)
- bushy starwort (*Symphyotrichum squamatum*)
- flaxleaf fleabane (*Conyza bonariensis, C. parva*)
- Paterson's curse (*Echium plantagineum*)
- tall fleabane (*Conyza sumatrensis*)
- white bartsia (*Bartsia trixago*)
- wild radish (*Raphanus raphanistrum*).

Figure 14. (below) Annual herb weeds that grow in wetlands. Photos – (a) SM Armstrong, KC Richardson and JF Smith; (b) R Randall; (c) G Byrne and KC Richardson; (d) J Dodd and R Knox; (e) L Fontanini, KC Richardson and JF Smith; (f) S M Armstrong. Images (a) – (f) used with permission of the Western Australian Herbarium, Department of Environment and Conservation http://florabase.dec.wa.gov.au/help/copyright, accessed 6/11/2009.

(a) blackberry nightshade (*Solanum nigrum*)

(b) flaxleaf fleabane (left, *Conyza bonariensis* and right, *Conyza parva*)

Figure 14. (continued)

(c) white bartsia (*Bartsia trixago*)

(d) Paterson's curse (*Echium plantagineum*)

(e) wild radish (*Raphanus raphanistrum*)

(f) bushy starwort (*Symphyotrichum squamatum*)

Perennial herbs

Perennial herbs have a life cycle of two or more years. Depending on species, they can reproduce by seed, stolons and rhizomes. Examples of perennial herbaceous weeds that can occur in wetlands include (see Figure 15):

- castor oil plant (*Ricinus communis*)
- dock (*Rumex* spp.)
- gentes herb (*Canna x generalis*)
- pennyroyal (*Mentha pulegium*)
- sorrel (*Acetosa vulgaris*).

Figure 15. (below) Perennial herbs that grow in wetlands. Photos – (a) I Morley/DEC; (b) G Keighery/Western Weeds; (c) JF Smith (d) J Dodd and KR Thiele; (e) R Knox; (f) K Brown/DEC. Images (c) – (e) used with permission of the Western Australian Herbarium, Department of Environment and Conservation http://florabase.dec.wa.gov.au/help/copyright, accessed 6/11/2009.

(a) curled dock (*Rumex crispus*)

(b) fiddle dock (*Rumex pulcher*)

(c) canna hybrid (*Canna* spp.)

(d) castor oil plant (*Ricinus communis*)

(e) pennyroyal (*Mentha pulegium*)

(f) blue periwinkle (*Vinca major*)

Sedges

Sedges are also classed as herbs or graminoids and refer to the grass-like species from the plant families including Juncaceae and Cyperaceae. The 'bulrush' refers to plants within the family Typhaceae (see below). Native sedges perform a vital role in wetlands, controlling erosion, maintaining water quality and providing habitat. However there are some species (both native and introduced) that can become invasive weeds in wetlands. Examples of weed species of sedges that can occur in wetlands include (see Figure 16):

- jointed rush (*Juncus articulatus*)
- spiny rush (*Juncus acutus*)
- tiny rush (*Juncus microcephalus*).
- budding club-rush (*Isolepis prolifera*)
- bunchy sedge (*Cyperus polystachyos*)
- club-rush (*Isolepis hystrix*)
- dense flat sedge (*Cyperus congestus*)
- divided sedge (*Carex divisa*)
- umbrella sedge (*Cyperus eragrostis*).

Sedge: tufted or spreading plant from the families Cyperaceae, Centrolepidaceae, Hydatellaceae, Juncaginaceae, Restionaceae, Juncaceae, Typhaceae and Xyridaceae. In these plants the leaf sheath is generally not split, there is no ligule, the leaf is not always flat and there is an extended internode below inflorescence. Some sedges are also known as rushes.

Figure 16. (below) Examples of rushes that are weeds that occur in wetlands. Photos – (a) GJ Keighery and JF Smith; (b) K Brown/DEC; (c) J F Smith; (d) K Bettink/DEC; (e) GJ Keighery and JF Smith; (f) BA Fuhrer. Images (a), (c), (e) and (f) used with permission of the Western Australian Herbarium, Department of Environment and Conservation http://florabase.dec.wa.gov.au/help/copyright, accessed 6/11/2009.

(a) bulrush (*Typha orientalis*)

(b) sharp rush (*Juncus acutus*)

(c) dense flat sedge (*Cyperus congestus*)

(d) *Isolepis hystrix*

Figure 16. (continued)

(e) bunchy sedge (*Cyperus polystachyos*)

(f) capitate rush (*Juncus capitatus*)

Typha

One of the most aggressive weeds of Western Australian wetlands is the introduced species *Typha orientalis*, a native of eastern Australia[9] (see Figure 17). The native species, *Typha domingensis*, is often mistaken for the introduced species, and both are commonly referred to as 'bulrush'. *Typha orientalis* is generally taller, with wider leaves and flower heads. The leaf blade of *T. domingensis* does not exceed 8 millimetres in width while the leaf blade of *T. orientalis* can be up to 14 millimetres wide (although exceptions exist making it difficult to distinguish between the two). Spreading from rhizomes, once established, *T. orientalis* rapidly forms a dense monoculture, suppressing all other vegetation. With each seed head producing up to 300,000 seeds, control is very difficult once established and requires vigilance for several years. *Typha* infestations can be linked to excessive nutrients within wetlands and/or altered hydrology whereby changes in wetland natural wetting/drying cycles can favour their establishment and dominance over native aquatic vegetation.

Figure 17. (below) (a) The introduced bulrush (*T. orientalis*) has formed a dense monoculture in Lake Mealup; (b) introduced typha seeds covering the soil surface; (c) seeds are easily spread by the wind. Photos – (a) N Landmann/DEC; (b) and (c) T Bell/DEC.

(a)

(b)

(c)

Weeds with corms, bulbs and tubers

This group of weeds possesses specialised underground fleshy storage organs known as corms, bulbs or tubers. These organs allow them to flourish in nutrient deficient soils or die back and enter a state of dormancy when conditions are extreme, such as during fire or drought.[8] Many species have spread from gardens, where they have been grown as ornamentals (for example arum lilies and freesias). Dumping of garden waste and soil in or near wetlands has assisted their spread and establishment. Their seed and underground reproductive structures can also be spread by water, wind, animals and by other human activities. Fire can also play a role in stimulating sprouting of dormant corms in the soil, which can remain viable for many years, in some cases longer than seed.

Figure 18. Two-leaf cape tulip (*Moraea miniata*) cormels. Photo – R Knox/Western Weeds.

The competitive advantage these weeds possess as a result of their underground storage organs, diverse reproductive strategies and ability to spread is considerable and, as such, they are a highly invasive and persistent group of weeds. Once established, they are extremely difficult to eradicate, particularly if a bank of dormant corms or bulbs has built up in the soil (see Figure 18). As a result, follow-up control may need to be undertaken for some years. Table 1 compares the differences between corms, bulbs and tubers.

Table 1. Comparison of life cycle and reproductive strategies of corms, bulbs and tubers

Type	Location of storage organ	Typical life cycle	Reproduction
Corms	Swollen underground stems or stem bases	Summer dormant, sprouting from corms in autumn. Produces one or two daughter corms annually	• Daughter corms • Cormels (small corms formed around the parent corm) • Axillary buds (that form new plants when the main growing shoot is removed) • Seed
Bulbs	Swollen underground leaf bases	Summer dormant, sprouting new leaves in autumn. Perennials produce one or two daughter bulbs annually	• Daughter bulbs • Bulbils (small bulbs formed at base of leaves or on underground stems, form new plants when detached) • Seed
Tubers	Swollen underground stems or roots, forming dense tuberous root mats	Usually summer dormant, re-sprouting in autumn	• New shoots arising from rhizomes • Seed

Examples of weeds with corms, bulbs and tubers that can occur in wetlands include (see Figure 19):

Corms

- freesia (*Freesia alba x leichtlinii*)
- harlequin flower (*Sparaxis bulbifera*)
- one-leaf cape tulip (*Moraea flaccida*)
- two-leaf cape tulip (*Moraea miniata*)
- watsonia (*Watsonia meriana*)

Bulbs

- belladonna lily (*Amaryllis belladonna*)
- soursob (*Oxalis pes-caprae*)
- three-cornered garlic (*Allium triquetrum*)

Tubers

- asparagus fern (*Asparagus aethiopicus*)
- arum lily (*Zantedeschia aethiopica*)
- bridal creeper (*A. asparagoides*)
- bridal veil (*A. declinatus*)

Figure 19. (below) Examples of cormous, bulbous and tuberous weeds that occur in wetlands. Photos – (a) L Fontanini; (b) A Shanahan/DEC and R Knox; (c) R Randall; (d) JP Pigott and R Randall; (e) R Randall; (f) KC Richardson and KR Thiele. Images (a) – (f) used with permission of the Western Australian Herbarium, Department of Environment and Conservation http://florabase.dec.wa.gov.au/help/copyright, accessed 6/11/2009.

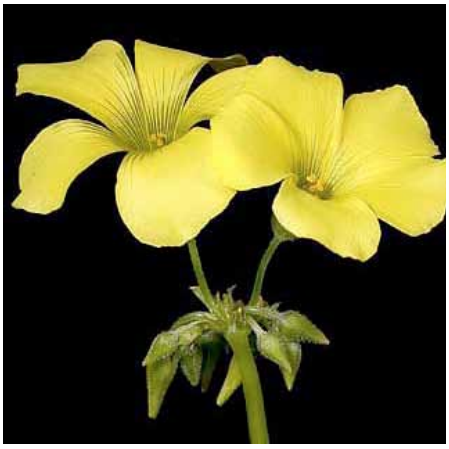
(a) three-cornered garlic (*Allium triquetrum*)

(b) two-leaf cape tulip (*Moraea miniata*)

(c) watsonia (*Watsonia meriana*)

(d) bridal creeper (*Asparagus asparagoides*)

(e) harlequin flower (*Sparaxis bulbifera*)



(f) soursob (*Oxalis pes-caprae*)

Woody weeds

Woody weeds are perennial weeds with woody stems including shrubs, trees and some vines. Most woody weeds reproduce by seed and some have a further advantage of being able to re-sprout from stems or branches (for example, after fire or lopping) or by means of a suckering root system (that is, re-sprouting from lateral roots). Woody weeds such as some vines can be problematic in wetlands when they form dense, impenetrable thickets which shade out and prevent germination of native species (see Figure 20). Removal of large woody weeds can be problematic, resulting in damage to surrounding vegetation, spread of seeds and secondary invasion of other weeds when light availability and temperature are increased following their removal (see Figure 21).

Figure 20. Passion vine (*Passiflora foetida*) infestation at Windjana Gorge. The fruits of this species are readily eaten by birds and mammals and distributed widely throughout the Kimberley. Passion vine dominates and smothers native vegetation, creating a higher fuel load in fire-sensitive ecosystems. Photo – L Williams/Environs Kimberley.

Figure 21. Coffee bush (*Leuceana leucocephala*) infestation along the foreshore of Roebuck Bay (Ramsar wetland). Spread by cattle and through water and soil movement, this species easily invades and dominates areas that have a history of disturbance. Photo – L Williams/Environs Kimberley.

Management and control of woody weeds should take into account re-sprouting/ suckering ability, risk of spreading seed and damage to surrounding vegetation, and secondary weed invasion. Examples of woody weeds that can occur in wetlands include (see Figure 22):

Trees

- athel pine (*Tamarix aphylla*)
- coral tree (*Erythrina* spp.)
- date palm (*Phoenix dactylifera*)
- poplar tree (*Populus* spp.)
- willow (*Salix babylonica*)

Small trees and shrubs

- buckthorn (*Rhamnus alaternus*)
- edible fig (*Ficus carica*)
- flax leaf paperbark (*Melaleuca linariifolia*)
- Japanese pepper (*Schinus terebinthifolia*)
- lantana (*Lantana camara*)
- olive (*Olea europaea*)
- sweet pittosporum (*Pittosporum undulatum*)
- Sydney golden wattle (*Acacia longifolia*)
- tagasaste (*Chamaecytisus palmensis*)
- taylorina (*Psoralea pinnata*)
- victorian tea tree (*Leptospermum laevigatum*)

Vines

- blue periwinkle (*Vinca major*)
- dolichos pea (*Dipogon lignosus*)
- Japanese honeysuckle (*Lonicera japonica*)
- morning glory and coast morning glory (*Ipomoea indica, I. cairica*)

Figure 22. (below) Examples of woody weeds that occur in wetlands. Photos – (a) I Morley/ DEC and A Fairs/DEC; (b) TC Daniell and M Hancock; (c) KC Richardson; (d) L Fontanini; (e) KC Richardson; (f) K Bettink/DEC; Images (b) – (e) used with permission of the Western Australian Herbarium, Department of Environment and Conservation http://florabase.dec.wa.gov.au/help/ copyright, accessed 6/11/2009.

(a) common fig (*Ficus carica*)

(b) Sydney golden wattle (*Acacia longifolia*)

(c) victorian tea tree (*Leptospermum laevigatum*)

(d) sweet pittosporum (*Pittosporum undulatum*)

(e)) athel pine (*Tamarix aphylla*)

(f) morning glory (*Ipomoea indica*)

extra information

Natives behaving like weeds

Some species of native wetland plants can behave like weeds if the wetlands in which they grow naturally are disturbed, or they are introduced (or spread) into areas outside of their natural range. Like weeds, these natives are opportunists that can take advantage of disturbed conditions, rapidly colonising areas to the exclusion of other native species. Native plants such as bracken fern (*Pteridium esculentum*) can form dense monocultures that alter the structure and diversity of wetland ecosystems (see Figure 23). Other examples of natives that can behave like weeds include:

- golden wreath wattle (*Acacia saligna*)
- native typha (*Typha domingensis*)
- marsh club-rush (*Bolboschoenus caldwellii*)
- white cedar (*Melia azedarach*).

Figure 23. (below) Photos – (a) T Bell/DEC; (b) A Ireland and J Smith. Image (b) used with permission of the Western Australian Herbarium, Department of Environment and Conservation http://florabase.dec.wa.gov.au/help/copyright, accessed 6/11/2009.

(a) Bracken fern (*Pteridium esculentum*) is an opportunist species.

(b) It can form dense thickets that smother out other native understorey vegetation.

Legislation and weeds

Declared plants in Western Australia

Plants that pose a serious threat to agriculture are declared under the *Agriculture and Related Resources Protection Act 1976*. Any landholder with declared plants on their property is required to control them at their own expense. For a complete list of declared plants in Western Australia, see the Department of Agriculture and Food WA website (www.agric.wa.gov.au).[10]

Weeds of national significance

Through the National Weeds Strategy framework, the Australian Government has identified twenty weeds of national significance (WONS). Due to their invasiveness, impacts and potential for spread, these weeds pose a serious threat to agriculture, forestry and the environment. Landowners with WONS on their property are responsible for their management at their own expense. A full list of WONS and management guidelines are available at www.weeds.gov.au.[11]

Aquatic plants: a plant that grows for some period of time in inundated conditions and depends on inundation to grow and, where applicable, flower

Aquatic weeds

Native aquatic plants perform vital functions in wetlands; they bind the sediment, provide habitat for aquatic fauna and help maintain optimal water quality. However, when some species (native and introduced) become highly abundant under certain conditions, they can severely alter wetland ecology.

➤ For additional detail on in the role of aquatic plants in wetlands, see the topic 'Wetland ecology' in Chapter 2.

Aquatic plants include plants that float with roots trailing in the water surface (floating aquatics) and those that are fully or partly submerged in the water with roots attached to the sediment (submergent aquatics). Introduced species of aquatic plants can enter wetlands in a number ways, for example, directly from disposal of pond, dam and aquarium plants and waste into wetlands, or indirectly via waterways and stormwater drains that feed into wetlands. Birds and other animals can also transport seed and plant material from backyard ponds or dams into wetlands.

Prolific growth of aquatic weeds is often a symptom of elevated levels of nutrients in the water or sediments, which can cause an increase in plant growth. If the right conditions occur, such as increased light intensity and water temperature in combination with high nutrient levels, an explosion in plant growth can occur. Factors that contribute to elevated nutrient levels may include the discharge of nutrient-rich stormwater into wetlands, uncontrolled livestock access or leaching of fertiliser from nearby agricultural areas and urban gardens and lawns. Elevated light intensity and water temperature in wetlands can result from a reduction in shading due to clearing of wetland vegetation such as overhanging trees.

➤ Algal blooms are also a symptom of elevated nutrients in wetlands. This is discussed in more detail in the topic 'Water quality' in Chapter 3.

A common feature of aquatic weeds is their ability to form a dense layer, or 'mat', above or below the water, blocking out light and depleting the water body of oxygen.[6] This can lead to the death of fish and other aquatic life and shading out of native aquatic plants. Salvinia (*Salvinia molesta*) is an example of an aquatic weed that forms a dense mat on the water surface, shading the water beneath it and restricting growth of algae and submerged aquatic plants (Figure 28). This prevents air entering the water body and subsequent deoxygenation can kill fish and other organisms.[6,12] Salvinia is listed as a declared plant in Western Australia and a WONS.

Serious aquatic weeds include (see Figure 24):

- alligator weed[2,3] (*Alternanthera philoxeriodes*)
- arrow head[3] (*Saggitaria montevidensis*)
- Brazilian water milfoil[3] (*Myriophyllum aquaticum)*
- Canadian pond weed[3] (*Elodea canadensis*)
- fanwort[2,3] (*Cabomba caroliniana*)
- horsetails[3] (*Equisetum arvense*)
- hydrocotyle[3] (*Hydrocotyle ranunculoides*)
- lagarosiphon[2,3] (*Lagarosiphon major*)
- leafy elodea[3] (*Egeria densa*)
- saggitaria[3] (*Saggitaria platyphylla*)
- salvinia[2,3] (*Salvinia molesta*)
- strap weed (*Vallisneria australis*)
- watercress (*Rorippa nasturtium-aquaticum*)
- water hyacinth[1,3] (*Eichhornia crassipes*)
- water lettuce[3] (*Pistia stratiotes*).

1 Appears on '100 of the World's Worst' invasive species list
2 Weed of National Significance
3 Declared in WA

Figure 24. (below) Examples of aquatic weeds that occur in wetlands. Photos – (a) BA Fuhrer; (b) R Knox and WA Herbarium; (c) R Knox and J Dodd; (d) R Davis; (e) AGWEST; (f) DJ Edinger. Images (a) – (f) used with permission of the Western Australian Herbarium, Department of Environment and Conservation http://florabase.dec.wa.gov.au/help/copyright, accessed 6/11/2009.

(a) *Crassula natans*

(b) water hyacinth (*Eichhornia crassipes*)

(c) hydrocotyle (*Hydrocotyle ranunculoides*)

(d) watercress (*Rorippa nasturtium-aquaticum*)

(e) water lettuce (*Pistia stratiotes*)

(f) common starwort (*Callitriche stagnalis*)

Priority wetland weeds for management in Western Australia

The Department of Environment and Conservation has identified weeds that are priorities for management in WA regions to protect environmental assets from the threat posed by established weeds and to allow more effective use of available resources for management. Priority wetland weeds are summarised in Table 2. Priority weeds for control have been determined according to their ecological impact, invasiveness, current and potential distribution and feasibility of control.

Table 2. Priority wetland weeds for management in Western Australia by region

(K Agar 2009, pers. comm.); based on Keighery G and Longman V (2004). ***The naturalised vascular plants of Western Australia 1: Checklist of environmental weeds and distribution in IBRA regions,*** Plant Protection Quarterly, Volume 19 (1), 2004)

Common name	**Scientific name**
Swan Region	
Athel pine	*Tamarix aphylla*[1,2,3]
Baboon flower	*Babiana angustifolia*
Blackberry	*Rubus* spp.
Brazilian pepper	*Schinus terebinthifolius*
Bulrush	*Typha orientalis*
Burrgrass	*Cenchrus echinatus*
Castor oil plant	*Ricinus communis*
Clubrush	*Isolepis hystrix*
Couch	*Cynodon dactylon*
Crassula	*Crassula natans* var. *natans*
Date palm	*Phoenix dactylifera*
Divided sedge	*Carex divisa*
Fern cotula	*Cotula bipinnate*
Haas grass, tribolium	*Tribolium uniolae*
Harlequin flower	*Sparaxis bulbifera*
Pampas grass	*Cortaderia selloana*
Parrot's feather or brazilian water milfoil	*Myriophyllum aquaticum*
Pond stonecrop	*Crassula natans* var. *minus*
Robust pennywort	*Hydrocotyle ranunculoides*
Sagittaria	*Sagittaria platyphylla*
Salvinia	*Salvinia molesta*[2,3]
Slender thistle	*Carduus pycnocephalus*
Sparaxis	*Sparaxis bulbifera*
Spiny rush	*Juncus acutus*
Sweet pittosporum	*Pittosporum undulatum*
Taro	*Colocasia esculenta* var. *esculenta*

Common name	Scientific name
Water hyacinth	*Eichhornia crassipes*[1,3]
Wavy gladiolus	*Gladiolus undulates*
South West Region	
African feather grass	*Pennisetum macrocouru*
Athel pine	*Tamarix aphylla*[1,2,3]
Blackberry	*Rubus* spp.
Brazilian pepper	*Schinus terebinthifolius*
Bulrush	*Typha orientalis*
Burrgrass	*Cenchrus echinatus*
Castor oil plant	*Ricinus communis*
Clubrush	*Isolepis hystrix*
Couch	*Cynodon dactylon*
Date palm	*Phoenix dactylifera*
Divided sedge	*Carex divisa*
Harlequin flower	*Sparaxis bulbifera*
Kikuyu	*Pennisetum clandestinum*
Puccinellia	*Puccinellia ciliata*
Salvinia	*Salvinia molesta*[2,3]
Spiny rush	*Juncus acutus*
Water hyacinth	*Eichhornia crassipes*[1,3]
Watercress	*Rorippa nasturtium-aquaticum*
Midwest Region	
African love grass	*Eragrostis curvula*
Athel pine	*Tamarix aphylla*[1,2,3]
Bulrush	*Typha orientalis*
Burrgrass	*Cenchrus echinatus*
Castor oil plant	*Ricinus communis*
Clubrush	*Isolepis hystrix*
Couch	*Cynodon dactylon*
Cyperus	*Cyperus* spp.
Date palm	*Phoenix dactylifera*
Divided sedge	*Carex divisa*
Feather top	*Pennisetum villosum*
Harlequin flower	*Sparaxis bulbifera*
Kikuyu	*Pennisetum clandestinum*
Morning glory	*Ipomoea cairica* and *I.indica*

Common name	Scientific name
One-leaf cape tulip	*Moraea flaccida*
Paspalum	*Paspalum dilatatum*
Salvinia	*Salvinia molesta*[2,3]
Spiny rush	*Juncus acutus*
Water hyacinth	*Eichhornia crassipes*[1,3]
Waterbuttons	*Cotula coronopifolia*
Watercress	Rorippa nasturtium-aquaticum
Pilbara Region	
African love grass	*Eragrostis curvula*
Athel pine	*Tamarix aphylla*[1,2,3]
Butterfly pea	*Clitoria ternatea*
Castor oil plant	*Ricinus communis*
Cotton palm	*Washingtonia filifera*
Cyperus	*Cyperus involcratus*
Date palm	*Phoenix dactylifera*
Parkinsonia	*Parkinsonia aculeata*
Stinking passion flower	*Passiflora foetida*
Bulrush	*Typha orientalis*
Goldfields Region	
Annual barbgrass	*Polypogon monspeliensis*
Athel pine	*Tamarix aphylla*
Blackberry nightshade	*Solanum nigrum*
Blue pimpernel	*Lysimachia arvensis*
Bulrush	*Typha orientalis*
Couch	*Cynodon dactylon*
Tamarisk	*Tamarix ramossisima*
Toad rush	*Juncus bufonius*
Kimberley Region	
Castor oil plant	*Ricinus communis*
Couch	*Cynodon dactylon*
Giant rubber bush	*Calotropis gigantea*
Mimosa, giant sensitive plant	*Mimosa pigra*
Mint weed	*Hyptis suaveolens*
Morning glory	*Ipomoea* spp.
Paragrass	*Urochloa mutica*
Parkinsonia	*Parkinsonia aculeata*

Common name	Scientific name
Rosella	*Hibiscus sabdariffa*
Rubber bush	*Calotropis procera*
Rubbervine	*Cryptostegia grandiflora*
Salvinia	*Salvinia molesta*
Stinking passion flower	*Passiflora foetida*
Water hyacinth	*Eichhornia crassipes*
Windmill grass	*Chloris virgata*
Zornia	*Ziziphus mauritiana*
Warren Region	
African feather grass	*Pennisetum macrocourum*
Athel pine	*Tamarix aphylla*[1,2,3]
Blackberry	*Rubus* spp.
Brazilian pepper	*Schinus terebinthifolius*
Bulrush	*Typha orientalis*
Burrgrass	*Cenchrus echinatus*
Castor oil plant	*Ricinus communis*
Clubrush	*Isolepis hystrix*
Couch	*Cynodon dactylon*
Date palm	*Phoenix dactylifera*
Divided sedge	*Carex divisa*
Harlequin flower	*Sparaxis bulbifera*
Kikuyu	*Pennisetum clandestinum*
Puccinellia	*Puccinellia ciliata*
Salvinia	*Salvinia molesta*[2,3]
Spiny rush	*Juncus acutus*
Water hyacinth	*Eichhornia crassipes*[1,3]
Watercress	*Rorippa nasturtium-aquaticum*
Wheatbelt Region	
Annual barbgrass	*Polypogon monspeliensis*
Blackberry nightshade	*Solanum nigrum*
Blue pimpernel	*Lysimachia arvensis*
Couch	*Cynodon dactylon*
Spiny rush	*Juncus acutus*
Tamarisk	*Tamarix parviflora*
Toad rush	*Juncus bufonius*
Bulrush	*Typha orientalis*

Common name	Scientific name
South Coast Region	
African love grass	*Eragrostis curvula*
African scurfpea	*Psoralea pinnata*
Arum lily	*Zantedeschia aethiopica*
Blackberry	*Rubus* spp.
Blue periwinkle	*Vinca major*
Cotton bush	*Gomphocarpus fruticosus*
Couch	*Cynodon dactylon*
Hedera	*Hedera helix*
Lantana	*Lantana camara*
Lesser canary grass	*Phalaris minor*
Morning glory	*Ipomoea indica*
Myrtleleaf milkwort	*Polygala myrtifolia*
Nutgrass	*Cyperus rotundus*
Pampas grass	*Cortaderia selloana*
Sagittaria	*Sagittaria platyphylla*
Saltwater couch	*Paspalum vaginatum*
Salvinia	*Salvinia molesta*
Senecio	*Senecio angulatus*
Sparaxis	*Sparaxis bulbifera*
Spiny rush	*Juncus acutus*
Stinkwort	*Dittrichia graveolens*
Sweet pittosporum	*Pittosporum undulatum*
Sydney golden wattle	*Acacia longifolia*
Three-cornered garlic	*Allium triquetrum*
Bulrush	*Typha orientalis*
Water couch	*Paspalum distichum*
Water hyacinth	*Eichhornia crassipes*
Watercress	*Rorippa nasturtium-aquaticum*
Watsonia	*Watsonia meriana* var. *bulbifera*
Wavy gladiolus	Gladiolus undulates

1 Appears on '100 of the World's Worst' invasive species list
2 Weed of National Significance
3 Declared plant in Western Australia

Key techniques for managing weeds in wetlands

Once established, weeds can be extremely difficult to eradicate and require consistent and sustained effort over time to bring them under control. Where infestations are severe, it may not be possible to completely remove weeds and ongoing efforts must instead focus on containment to prevent further spread. Before embarking on a weed control program, some guiding principles should first be considered to ensure success and avoid wasted time, money and effort.

Despite the very best intentions, weed control programs almost always fail if vital information about the weeds and site conditions are not taken into account. It can also be easy to underestimate how much time may be required for follow-up weed control and therefore initial plans may need to be scaled back once all the information is taken into account to ensure a successful result. To fail to plan is to plan to fail!

Aim of weed control

The weed control strategies presented in this topic are aimed at protecting and conserving wetland values, particularly biodiversity. Weed control measures that have the potential to have direct or indirect adverse effects on biodiversity should be carefully considered before being implemented. For example, the use of certain herbicides that are extremely effective in controlling particular weeds may have unacceptable impacts on non-target native plants and/or wetland animals. Similarly, the removal of weeds that provide habitat for native fauna may result in fauna losses due to predation, exposure to the elements and removal of food sources.

In such cases, weed management measures may need to be modified, or perhaps even abandoned if damage to the environment is at a level considered to be detrimental to biodiversity conservation aims. Where negative impacts are likely, but at a manageable level, it is important to assess which native species are likely to be affected, what the level of impact will be, how impacts will be managed and the pros and cons of these impacts versus the long-term benefits to biodiversity.

Ideally, a weed control program should form part of an overall wetland management plan to ensure that weed control activities not only meet wetland management goals but are undertaken at the most appropriate time in conjunction with other wetland management activities, including encouraging native vegetation regeneration. A wetland management plan will assist in identifying priority wetland management actions and where, when and how these should be undertaken. For example, in some situations, weed control may not be the highest priority for management where other issues pose a higher threat to wetland biodiversity values.

➤ For additional detail on wetland management planning, see the topic ‘Wetland management planning’ in Chapter 1.

Weed management versus weed eradication

It should be noted that weed management does not necessarily imply complete and permanent removal of every single weed in a given area. In many cases, complete removal of weeds is not feasible or desirable for many reasons; for example, limited resources, increased potential for erosion or other adverse environmental impacts.

Prevention is the key

The best strategy for controlling weeds is to prevent weeds from becoming established in the first place and to act quickly following any new weed invasions. Once weeds have become established, weed control should ideally start in the least affected areas and move towards the most affected areas.

Consideration of the causes of weed infestations may identify other factors that may need to be addressed prior to, or simultaneously with, weed control. For example, where excess nutrients are stimulating growth of aquatic weeds, removal of the source or implementation of measures to ameliorate the impacts of nutrients may need to be undertaken as a matter of priority.

Guiding principles to prevent weeds from becoming established in wetlands include:

Prevent introduction of weeds from wind and water:

- Identify where weeds could be transported from via wind and water and implement measures to reduce the risk of invasion (for example, undertaking weed control in nearby paddocks or road verges).
- Remove known aquatic weeds from nearby garden ponds, drains or dams.
- Restore native dryland vegetation adjacent to wetlands and establish **shelterbelts** around property boundaries (using fast-growing **indigenous/local provenance** dryland plants) to stop weeds from blowing in or entering via runoff to act as a barrier to weed invasion.

Prevent introduction of weeds from human and livestock movement:

- Prevent or minimise access to wetlands via vehicles, livestock and humans.
- Before entry onto properties and/or wetland vicinity, clean weed seeds from vehicles, machinery, tools, pets and livestock, clothing and boots.
- Prevent disposal of garden prunings or lawn clippings from gardens into or around wetlands.
- Protect wetland vegetation from grazing, disturbance and clearing by fencing off areas of native vegetation.
- Prevent direct disposal of aquatic plants from ponds, dams or aquaria into wetlands, waterways or drains.

Reduce susceptibility of the site to weed establishment:

- Avoid disturbing existing native vegetation as this is where weeds will invade.
- Reduce or eliminate sources of nutrients entering wetlands that could stimulate the growth of weeds (for example, by ensuring fertiliser applied to gardens, lawns and paddocks does not leach into wetlands).
- Reduce fuel loads and risk of fire (and hence growth of weeds following an unplanned fire).

Early detection and control:

- Undertake regular monitoring to check for new weed infestations and remove them as soon as possible.

Indigenous: a species that occurs at a place within its historically known natural range and that forms part of the natural biodiversity of a place

Local provenance: indigenous plants propagated from collections from locations as close as geographically (in terms of habitat) practicable to the location where the propagated plants are to be planted. This ensures that genetic integrity is maintained

Shelterbelts: belts or rows of trees and shrubs planted to provide protection against prevailing winds

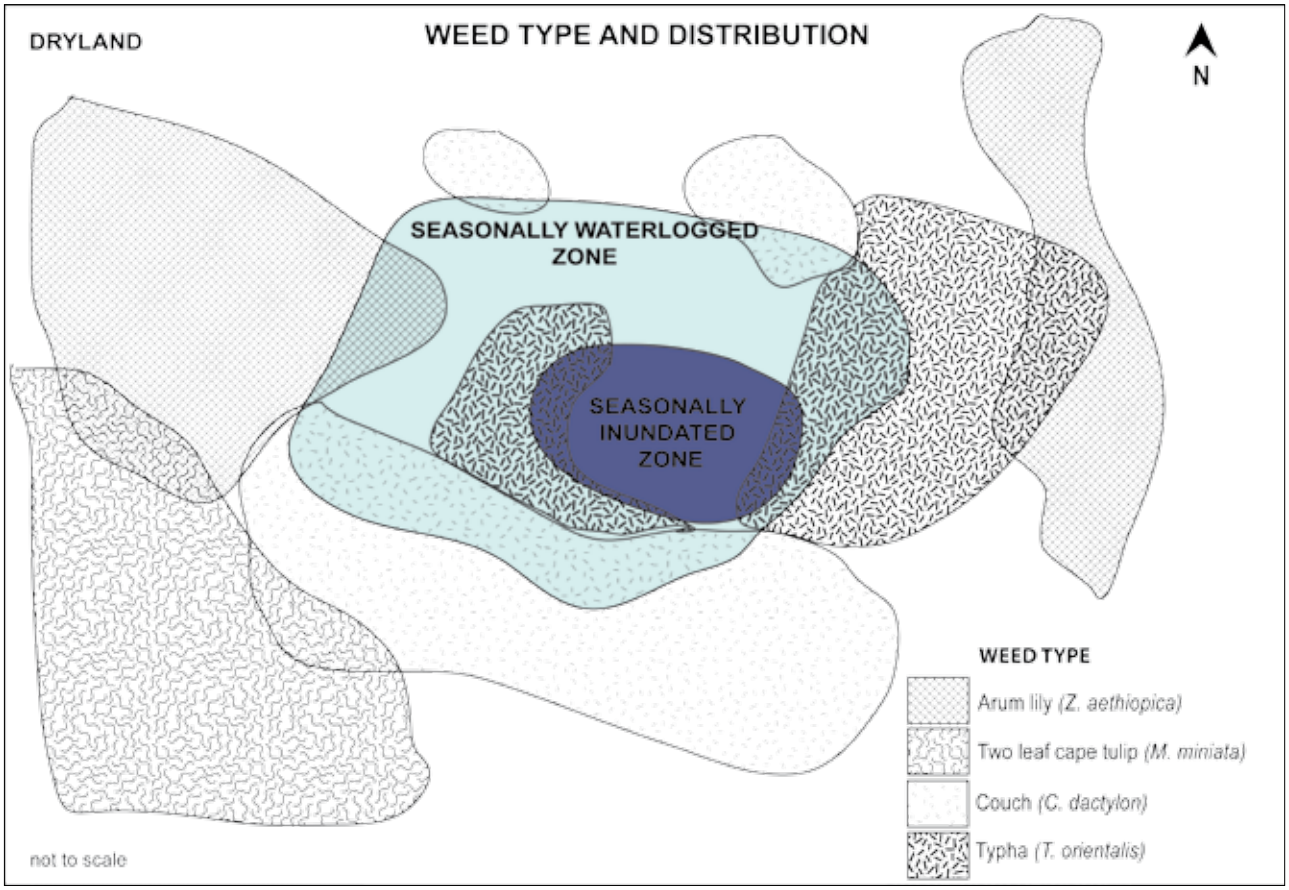
Weed identification is the key to successful weed control

For weed control to be successful, it is essential to accurately identify weed species to ensure that the most appropriate control methods are chosen. This will also minimise the risk of mistaking 'weedy' looking native plants as weeds! For additional detail on weed identification see the 'Sources of more information' section at the end of this topic

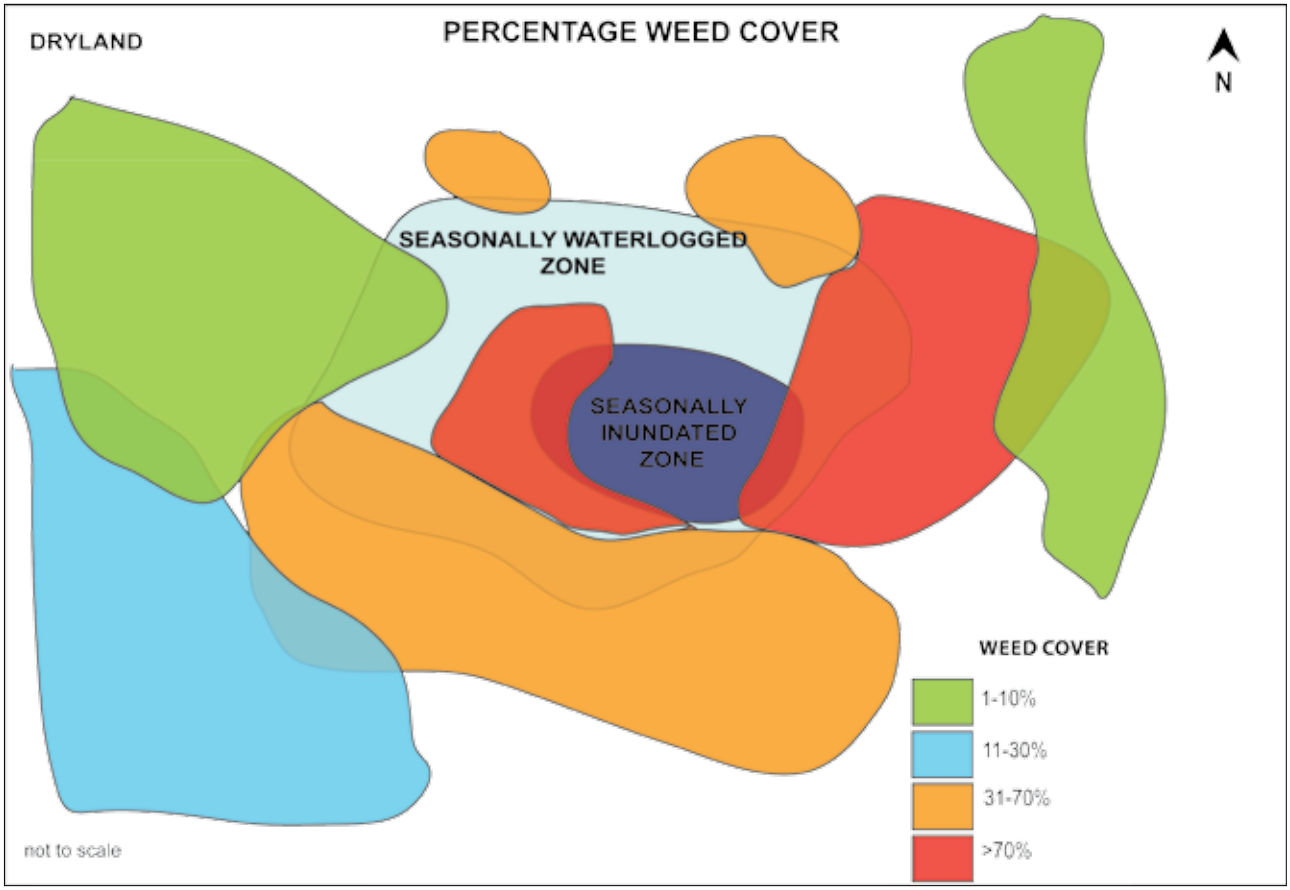
Weed mapping

Mapping individual weed species can assist in prioritising weeds for control. Ideally, weed mapping should be done in conjunction with mapping wetland vegetation communities to identify areas of native vegetation that are priorities for preventing and/or controlling weed invasion. Vegetation maps can be overlain with a weed map to show where serious weeds occur, extent of infestations (distribution and percent cover) and the rate and direction in which they are spreading. Not all weeds need to be mapped, just those that have the most serious, or potential for serious impacts on the site (see Figure 25). An aerial photo of the site provides a good basis for developing vegetation and weed maps to ensure that maps are to scale and important features in and around the wetland are incorporated.

Figure 25. (below) Examples of simple wetland weed maps which overlay an aerial photograph of the wetland and a wetland vegetation condition map – (a) weed type and distribution and (b) percentage weed cover.



(a)



(b)

Weed mapping can also help identify how and from where weeds are spreading, or have the potential to spread into the wetland area. For instance, tracks through the wetland or adjacent paddocks may be the source of highly invasive grass (pasture) weeds such as couch (*Cynodon dactylon*) and kikuyu (*Pennisetum clandestinum*). Similarly, agricultural or stormwater drains that are connected to wetlands may be the source of aquatic weeds. If weeds originate from neighbouring properties, working with neighbours in a joint effort to control weeds will ensure a more effective long-term outcome and better use of resources.

Mapping can also identify other areas of the wetland that are disturbed (or at risk from disturbance), or influenced by other factors that promote weed invasion. High fire risk areas can also be identified, which may be a critical factor in determining priority areas for weed control. Consideration of other factors such as climate, season, topography, wetland hydrology and fauna communities will also assist in deciding where, when and how weed control efforts will be most effective.

A weed map does not need to be complicated and requires only a few items including an aerial photograph of the wetland or property (on a size A4 or A3 sheet, at a scale of between 1:1,000 and 1:2,000 is ideal, depending on the size of the wetland), plastic overlay sheets and permanent marker pens.

➤ Aerial photographs may be sourced from local government authorities (councils or shires) or landcare centres. Rural landholders can source them from the Small Landholder Information Service (Department of Agriculture and Food, www.agric.wa.gov.au). Alternatively, Google Maps can also be useful for printing out reasonable quality aerial photos at no cost.

Mapping one weed at a time is the simplest approach (and remember, not all weeds need to be mapped, just those that present the greatest threat to the wetland). Many weeds grow in distinct zones. Use easily distinguishable features on the aerial photograph to assist in determining the boundaries of weed infestation zones (such as large trees, tracks, fence lines, inundated areas and so on). The boundary around each zone should be drawn on the plastic sheet (overlaying the aerial photograph) using the marker pens, indicating the name of the weed(s) in each zone. It can also be helpful to estimate the per cent of weed cover for each weed species, indicated using a colour code. For example:

- light infestation (i.e. weed forms 1–10 per cent of ground cover) = green
- light – medium infestation (i.e. weed forms 11–30 per cent of ground cover) = blue
- medium – heavy infestation (i.e. weed forms 31–70 per cent ground cover) = orange
- heavy infestation (i.e. weed forms greater than 70 per cent ground cover) = red.

Once the map is completed, this can be used to overlay a vegetation condition map to determine the highest priority areas for control. Small isolated patches of serious weeds in relatively undisturbed areas of native vegetation are usually the highest priorities for weed control (that is, following the weed control principle of working from the least weed affected areas, outwards towards the worst affected areas). Overlaying the weed map over the vegetation condition map is also useful for highlighting particular associations between certain weed species and plant communities or soil types.

➤ The step-by-step instructions used by DEC officers to map weeds are available at www.dec.wa.gov.au/monitoring/standard-operating-procedures.html

➤ For additional detail on wetland vegetation mapping, see the topic ‘Managing wetland vegetation’ in Chapter 3.

The basic principles of a weed management program

- Prevent spread, or further spread, of serious weeds into areas of intact vegetation.
- Avoid disturbing intact vegetation as this can lead to weed invasion.
- Work in areas that have the capacity to regenerate (i.e. where native vegetation can recover and grow back naturally following weed control).
- Develop a weed management plan (incorporating weed and vegetation condition maps to identify priorities for weed control).
- Control weeds as soon as they appear, working from areas least affected towards areas most affected.
- Where possible, revegetate disturbed or degraded areas that harbour serious weeds and that continue to provide a source of seed that can spread into other areas. Although this is a lower priority than protecting the least invaded areas of vegetation, it should be incorporated into long-term weed control program actions.
- Undertake a social program to educate neighbours and others contributing to the spread of weeds, and encourage their active participation in the solution.

How much weed control and when?

Resources and timing

The size of the area, amount of weeds to be controlled and rate of control should be dictated by the resources available and the rate at which natural regeneration or revegetation is expected to occur following removal of weeds. This will ensure that weed control measures and follow-up weed control is manageable, and bare areas left by weed control will be colonised by native plants and not the next crop of weeds. The best time to control weeds is as soon as possible after invasion, while numbers are low. Once weeds have become established and a major infestation results, weed control is much more difficult and costly in terms of time, labour and money.

Planning and prioritisation

In order to achieve successful outcomes, a detailed implementation plan is essential. The plan should identify priority weeds for control, how weeds will be controlled, when weeds will be controlled, and required materials, labour and costings for each phase of the weed control program. Details for follow-up weed control should be also be included, as well as requirements for ongoing monitoring of the site.

Prioritising weed species for control should take into account their invasiveness, distribution and impacts on the wetland. Prioritisation of weeds can be assisted by undertaking a weed map of the site, identifying the areas or zones where control should occur (discussed in more detail under the heading ‘Weed mapping’). The plan may need to be modified if unexpected events occur, such as fire, disease or reduction in the level of resources (for example, available time and money) to undertake planned activities. In the case of a fire, weed control may need to be diverted to areas that have been burned to minimise the risk of major weed infestation post fire. Growth of annual grasses and weeds with bulbs and corms can be especially vigorous post fire and therefore weed control should be undertaken as soon as germinants start to appear (see Figure 26).

Figure 26. Weed control should be undertaken as soon as weed germinants appear following a fire. Photo – N Hamilton/DEC.

Table 3 provides an example of a basic weed control implementation plan (note: different weed species require control at different times of the year and a weed control implementation plan should reflect this).

Follow-up

With most weed control programs, it is necessary to weed the site more than once to get the weed population(s) under control. When weeds are killed (for example, by spraying) or physically removed (for example, digging out or hand pulling), this can create conditions that stimulate further germination of weed seeds, corms or bulbs lying dormant in the soil. For weed control to be successful, follow-up weeding is essential to ensure the new batch of weeds does not become established and out-compete regenerating native plants or seedlings.

Weed succession

Sometimes the removal of one type of weed can encourage the growth of other weed species, so follow-up weed control may need to employ a different strategy to the initial control. Follow-up weeding will need to be ongoing and for several years at least, depending on the site conditions, weed species present and rate and success of regeneration or revegetation. Progressively less follow-up weeding should be required once native plants are regenerating well and at a rate faster than weeds can become re-established.

Most weed species maintain a soil seed bank for at least several years, and others will continue to re-invade until re-established native vegetation has reached sufficient density. A program of at least three years will be required to achieve maintenance level management; in almost all cases, weed control maintenance will need to continue over the long term (at least 10 years), unless the original disturbance mechanisms have been arrested, and adjacent weed sources controlled.[5]

In some instances, it may be more effective to manage weeds at a local catchment scale, especially if they originate from outside the property boundary. Working with neighbours or the local government council in a joint effort to control the most problematic weeds in a local area may be a more effective use of resources, and increase the likelihood of success in the long term.

Table 3. Basic weed control implementation plan

				Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Activity	**Who**	**Cost**	**Hours**	**2009**	**2009**	**2009**	**2009**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**
Weed mapping	Mary	$ -	4																
Mark zones for control	Mary	$ -	1																
Order native seedlings, fertiliser	Mary	$150	2																
Purchase chemical, backpack/ sprayer	Mary	$300	2																
Book spray contractor	Mary	$-	0.5																
Weed control zones 1 and 2	Contractor	$250																	
First follow-up weed control	Contractor	$100																	
Revegetation* zones 1 and 2	Mary	$ -	10																
Second follow-up weed control	Mary	$ -	4																
Third follow-up weed control	Mary	$-	4																
Monthly monitoring of weeds and native seedlings	Mary	$ -	6																
TOTAL		$800	33.5																

*Note: In some situations, weed control may need to be continued for several years before revegetation (or natural regeneration) can occur.

The big picture

Finally, proposed or existing weed management programs should be considered in view of the ecosystem as a whole to avoid causing more harm than good. For example, there may be instances where weeds are not causing significant impacts on biodiversity (and are not likely to in the future) and removal of these weeds may result in more aggressive weeds replacing them. This is especially critical in situations where follow-up weed control and/or regeneration or revegetation is unlikely to occur or may be unreliable (for example, due to limited labour or resources, other difficulties such as site access etc).

extra information

Benefits of weeds in wetlands

In some circumstances, weeds may provide a source of food or habitat for native fauna and a corridor for them to move safely from one area to another. Ideally, weed control should be undertaken gradually to allow fauna time to find alternative habitat and followed up with revegetation with native species. Weeds can also play an important role in reducing nutrients and sediments from entering wetlands and affecting water quality. In this situation, interim soil stabilisation and/or sediment trapping methods may be required between weed removal and natural regeneration or revegetation.

Weed control methods

This section outlines the main methods of control of wetland weeds and when they are best used. The weed control methods include:

- manual control
- mechanical control
- suppression
- barriers
- flame and steam weeding
- biological control
- controlled grazing
- chemical control
- integrated weed control.

To achieve best results, one method or a combination of methods (integrated weed control) is often the best approach, depending on the type and extent of the weed problem, site conditions and available resources (for example, time, labour, money).

Table 4 summarises the control options for the major types of wetland weeds. These are discussed in more detail in the following sections.

Table 4. Control options for major types of wetland weeds

Weed type	Control options
Annual grasses	Small infestations: • Hand pull or dig up entire plant prior to seed set (note: crowning may be a better option where pulling up or digging out weeds is difficult or causes major soil disturbance); and/or • Flame or steam weed (note: first assess the level of risk for causing fires, especially in peat areas). Larger infestations: • Mow or slash prior to seed set; and/or • Apply recommended herbicide early in the growing season when plants are small (3–5 leaf stage). Use a grass-selective herbicide if grass is growing amongst native vegetation and ensure native grasses will not be damaged.
Perennial grasses	*Tussock grasses* Small infestations: • Remove entire plant prior to seed set, or when dealing with larger areas or difficult-to-remove plants, use a knife to cut through roots below crown tissue at the base of the stem (removing all dormant buds at the base). Larger infestations: • Mow or slash after the flower head has emerged but prior to seed set. Slashing is most effective when followed up with herbicide treatment. *Stoloniferous or rhizomatous grasses* Small infestations: • Hand weeding is not recommended due to the difficulty in removing all stem and root material and the resulting soil disturbance; • Flame or steam weeding; follow-up treatments may be required; and/or • Solarisation; for summer active plants in moist soil. Larger infestations: • Weed barriers; constructed or through revegetation; • Shading out through revegetation; and/or • Apply recommended herbicide during the growing season when plants are small.
Broadleaf herbs	Small infestations: • Hand pull or dig up entire plant before seed set; and/or • Flame or steam weeding. Larger infestations: • Mow or slash after flower head has emerged but prior to seed set; and/or • Apply recommended herbicide during the growing season before flowering when plants are small and actively growing.
Corms, bulbs and tubers	Small infestations: • Remove entire plant (usually early in the growing season, before seed set), ensuring no bulbils or daughter corms are left in the soil. Larger infestations: • Undertake repeated mowing or slashing after flower head has emerged but prior to seed set to avoid spreading seed. Slashing is most effective when followed up with herbicide treatment; and • Apply recommended herbicide at the correct stage of lifecycle, usually just before or just on flowering (this can vary depending on the species, seek expert advice).
Woody weeds	Small infestations: • Remove entire plant (hand pull, digging out). Larger infestations: • Apply recommended herbicide using most appropriate technique, i.e., foliar spray, cut and paint, basal bark spraying, scrape and paint, stem injection, stem and leaf wiping.

Manual control

This includes hand pulling and digging, crowning, and hand removal of aquatic weeds. Manual control methods are useful where there may be concerns about the impact of machinery or herbicides on the environment, and where there are smaller areas of weed infestation. Where appropriate, manual control may be more effective when combined with herbicide application to minimise soil disturbance.

Hand pulling and digging

This method can be used with success where weed numbers are low, where weed control is taking place in a localised area and if the weeds are easy to pull or dig up. It may be the preferred method where weeds are growing amongst sensitive areas of vegetation, where other methods of removal may cause an unacceptable level of disturbance or risk damage to native plants. The keys to success are to ensure that hand pulling and digging is done prior to the weeds seeding and that all of the plant material that is capable of germinating or regenerating is removed from the soil. This includes seed pods and capsules, roots, bulbs, corms, tubers, rhizomes and stolons. In the case of weeds with bulbs and corms, following removal of the parent bulb/corm, the remaining soil must be carefully checked to ensure that any daughter bulbs or corms are not left behind as these can sprout and grow rapidly to form a secondary infestation. If bulbs and corms are present, they must be bagged and removed from the site together with the immediately surrounding soil. It should be noted that soil disturbance from hand pulling and digging can encourage weed seeds to germinate; therefore, follow-up weed control is likely to be required.

Crowning

This technique is useful for weeds that can re-sprout from structures beneath the soil, such as crowns, corms and rhizomes, and clumped or tufted fibrous root systems. A knife or other sharp object is inserted at an angle into the soil and the roots are severed to enable the plant to be removed. It is essential to remove the section the roots attach to, the '**crown**', as this can re-sprout if left in the ground.

Hand removal of aquatic weeds

Floating and submerged aquatic weeds are often best removed by hand to avoid damage to native aquatic vegetation and risks associated with using herbicides in wetlands. Floating aquatic weeds can be harvested by hand, using long-handled rakes for instance, and collected plant material stored in bags for solarisation, composting or landfill disposal. Use of bunds may be useful for larger areas to prevent aquatic weeds from entering 'weeded' out or uninfested areas.

Mechanical control

Mechanical removal is suited to managing large areas of weeds, inaccessible areas due to thick infestations and for aquatic weeds. Methods include mechanical slashing, mowing, cutting, cultivation, scraping and harvesting.

Crown: the region of compressed stem tissue from which new shoots are produced, generally found near the surface of the soil

Slashing, mowing and cutting

In the case of areas completely dominated by annual grasses, this option provides the added advantage of reducing fuel load and hence fire risk when weeds die off over summer. This method is suitable for areas in which native vegetation is not present or is growing in isolated patches that can be avoided, thereby minimising damage from machinery. Slashing and mowing should be done before seed set, to avoid spreading seed around the site. This method does not usually kill weeds straight away, but it serves to deplete their energy reserves and prevent seeding.

Slashing and mowing may need to be repeated several times over the year following if regrowth occurs. This method can be used in combination with chemical control, by spraying regrowth with an appropriate herbicide following slashing and mowing. Using heavy machinery to control weeds should be considered very carefully as it has the potential to compact wetland soils (see Figure 27). This soil damage can in turn make it harder to revegetate the area, reduce the habitat of soil dwelling and burrowing animals, and alter drainage patterns.

Figure 27. Slashing bulrush (*Typha orientalis*) at Forrestdale Lake. Stems are sprayed following slashing to prevent regrowth. Photo – T Bell/DEC.

case study

Salvinia and native bulrush control in Lily Creek Lagoon, Kununurra

Approximately 135 hectares in area, Lily Creek Lagoon in Kununurra is part of the Ramsar wetland site that encompasses Lakes Kununurra and Argyle. It is directly connected to Lake Kununurra, the supply dam for the irrigation area and environmental flows to the Lower Ord River. The township of Kununurra wraps around Lily Creek Lagoon, which is an important habitat for migratory birds, freshwater crocodiles and numerous species of fish. It also provides an attractive backdrop and recreational area for the town.

A small infestation of salvinia (*Salvinia molesta*) was first discovered by a local resident in May 2000. It was immediately identified to be of major concern due to its potential to completely smother the water body and cause damage to the native aquatic ecosystem. It is also of concern as this is the only current infestation in the north of WA and establishment could see it spread through the use of boat trailers to the pristine waterways of the Kimberley.

The control and eradication process of salvinia has been a joint effort of the Shire of Wyndham-East Kimberley, Ord Land and Water, Water Corporation, Department of Water, Department of Environment and Conservation, Department of Agriculture and Food and Save Endangered East Kimberley Species. The initial short-term goal was to contain the isolated infestation, preventing it from spreading throughout Lily Creek Lagoon, Lake Kununurra and Lower Ord River. The long-term goal was for complete eradication due to the serious nature of the weed and the small scale of the infestation.

Several different methods have been used over the past nine years to eradicate salvinia. Initial controls involved the containment of the weed through a boom fence and the manual removal of the bulk of the salvinia where possible. This was followed up by spraying with Roundup Biactive®, and installation of more boom fences (see Figure 28).

The floating boom fences, which are partly submerged beneath the surface to about 35cm depth, are designed to trap salvinia and prevent it from spreading to uninfested areas. Initially one boom fence was used for containment, with more booms being installed later to create additional holding cells. The holding cells served two functions, to trap salvinia that was regenerating from small pieces missed hiding in the native typha stands, and to trap any new plants entering the lagoon from the drain leading into it.

The major difficulty of salvinia being trapped within dense stands of native typha made access for control and removal very difficult. A clearing permit was obtained to remove a small area of native typha in order to allow greater access to the salvinia infestations. The most successful strategy for controlling native typha was mechanical removal with follow up spraying of regrowth. An excavator was used to remove approximately 600 square metres of native typha, which created an open water area which allowed access for eradication of salvinia. Removal of native typha was undertaken outside the breeding season of the swamp hen, which relies on the dense stands for nesting.

Given the total area of native typha within Lily Creek Lagoon is approximately 72 hectares, the loss of this small section has prevented salvinia from invading the remaining native typha in the lagoon, which would have been disastrous. Its removal from the control area improved the effectiveness of the salvinia control as only several small clumps have since been found and these were easily removed by hand.

Monthly monitoring is undertaken to ensure any new infestation are identified and eradicated early. No salvinia has been found since October 2007 and therefore it is likely that it has been eradicated. Lilies and other aquatic plants have regrown in the control area effectively rehabilitating it. If by October 2009 no salvinia is found, the area will be declared clear of salvinia and monitoring frequency will be reduced.

A pamphlet was produced for the community describing salvinia and the threat it poses to the environment, industry and lifestyle. A media campaign was also run, with articles in local papers, radio interviews and displays at the Kununurra Show, natural resource management field days and conferences. Signs have also been erected at the site informing the public of the salvinia quarantine area.

case study

Figure 28. (below) (a) Salvinia monitoring and collection; (b) salvinia trapped within stands of native typha; (c) salvinia containment area using boom fences. Photos – D Pasfield/Ord Land and Water.

(a)

(b)

(c)

Cultivation and scalping

Cultivation is generally not recommended for weed control in a bushland or wetland environment as it involves breaking up the weeds and turning the soil. This can spread weed seeds and other plant parts capable of regenerating, damage native plants and create conditions that favour secondary weed invasion, such as increased space and light. This method may be useful in large, degraded areas where there is no native vegetation present or as a pre-cursor to direct seeding, which requires a completely weed free environment.

Follow-up weed control after direct seeding a cultivated site needs to be vigilant to prevent establishment of the next weed crop that is guaranteed to emerge. This may best be achieved by using an appropriate selective herbicide, and when planting native seedlings a thick layer of mulch can be applied to suppress secondary weed growth.

Scalping involves slicing off the top layer of soil which contains the weeds and weed seeds, leaving the surface bare in preparation for revegetation. Scalping can be done by hand using a sharp shovel for small areas, or with a tree planting machine or road grader for larger areas. Once again, follow-up weed control is important to deal with secondary weed growth which may out-compete establishing native vegetation.

Aquatic weed harvester

In situations where aquatic weeds dominate large wetlands (particularly lakes) and where hand harvesting, spraying or other weed control options are not feasible, aquatic weed harvesters can be used to remove large amounts of weeds. These machines can be purchased in Australia and have been used with varying degrees of success in Western Australia. An aquatic weed harvester typically has large cutting blades that cut the weed above the sediment layer (see Figure 29). Harvesters remove submerged aquatic weeds such as introduced or native typha and floating aquatic weeds such as salvinia. The disadvantage with aquatic weed harvesters is they are expensive to purchase and they can cause damage to native aquatic vegetation and disturb the sediment layer, causing increased turbidity and re-suspension of nutrients or other pollutants. Harvested weeds must be disposed of appropriately to avoid causing odour or other problems (such as leaching of nutrients) from decomposition of plant material.

Figure 29. Aquatic weed harvester removing native typha and salvinia. Photo – K Tripp/Shire of Wyndham East Kimberley.

Weed suppression

Weed suppression methods aim to suppress conditions that favour weed establishment such as soil disturbance and increased light, nutrients and space. Weeds can be suppressed by smothering, mulching, solarisation and drowning.

Smothering and mulching

Depending on the site and type of weeds present, using thick layers of mulch or other materials, including carpet or weed matting, can be very useful in discouraging weed growth. The layers of mulch or matting effectively reduce light and thus prevent weeds from **photosynthesising**. For very aggressive or persistent weeds, conveyor belt rubber is excellent as it forms an impenetrable layer which can be removed once weeds have completely died off. The smothering technique is particularly useful in areas that are dominated by weeds and have no native plants present, where very vigorous and invasive weeds such as couch (*Cynodon dactylon*) and kikuyu (*Pennisetum clandestinum*) are present, or in situations where use of chemicals or other methods are unsuitable.

Solarisation

This method involves covering weeds with ultraviolet-resistant black plastic sheeting and making use of the sun's energy to kill weeds and weed seeds. This method is useful for treating summer-growing grasses in highly disturbed areas during summer, where the soil is moist. The time taken to kill weeds will depend on the weed species, season applied and intensity of the sun. A minimum of four weeks is usually required. Follow-up chemical control may be required, particularly in the case of stoloniferous or rhizomatous grasses such as kikuyu (*P. clandestinum*) and couch (*C. dactylon*), which may re-sprout following treatment. Plastic bags can also be used to sterilise weeds that need to be removed from the site and disposed of, thus reducing the chance of spreading seed or plant parts that can re-sprout. This usually involves placing weed seed heads that have been removed into black plastic bags and placing these in the sun until all plant parts are 'cooked' before disposal.

Drowning

This method can be effective for **emergent** aquatic weeds such as *Typha orientalis*. The plant is drowned by cutting the shoot below the water surface. This may need to be repeated several times over a season to completely kill the plant. There may be insufficient water depth for this method to be effective in killing weeds growing near the water's edge.

Barriers

Natural and constructed physical barriers can be effective weed control measures.

Revegetation

Dense native vegetation can provide an excellent natural weed barrier and therefore weed control programs should include restoration of native vegetation wherever possible. Native vegetation not only competes with weeds for light, nutrients and moisture, it provides a physical barrier which can prevent the entry of wind and water borne seeds into sensitive areas (see Figure 30).

Constructed weed barriers

These can be very effective by providing a physical obstacle that prevents the spread of turf grass or pasture (for example, couch, kikuyu, buffalo grass) from lawn areas or paddocks into sensitive natural areas. The barriers are constructed along the boundary of the area to be protected by digging a trench at least 50–60 centimetres deep and placing materials such as weed mesh or rubber conveyor belt vertically into the ground as a barrier to stop rhizomes from creeping through. The trench is backfilled and, where appropriate, concrete kerbing (or similar) may be placed on top to provide a 'mowing'

Photosynthesis: the process in which plants, algae and some bacteria use the energy of sunlight to convert water and carbon dioxide into carbohydrates they need for growth and oxygen

Emergent: a plant that is protruding above the surface of the water or, where a water column is not present, above the wetland soils (as distinct from floating or submerged plants)

Figure 30. Couch (*Cynodon dactylon*) and kikuyu (*Pennisetum clandestinum*) are unable to penetrate a dense stand of the native sedge *Baumea articulata*. Photo – T Bell/DEC.

Figure 31. Concrete kerbing provides an ideal weed barrier, preventing grass weeds from nearby lawn areas from invading newly revegetated areas. Photo – D Moort/City of Rockingham.

edge and further barrier for stolons creeping across the soil surface (see Figure 31). Pedestrian footpaths can also be used as an effective barrier.

Controlled grazing

In certain circumstances and with proper management, controlled grazing can be used to keep weeds, particularly pasture grasses, under control. It must only be used when grazing is a legal activity and does not have the potential to cause environmental harm. It is important to be aware that grazing is a form of clearing (due to its impact on native vegetation) that is subject to regulations of the *Environmental Protection Act 1986*. Furthermore, grazing should not be introduced to areas where it has not previously occurred. Activities such as increasing the stocking rate on native pastures or grazing regenerated areas may constitute clearing of native vegetation and will require a clearing permit if an exemption does not apply.

➤ For additional detail on clearing regulations and managing livestock in wetlands, see the topic 'Livestock' in Chapter 3.

Grazing is most suited to situations in which livestock access can be strictly controlled within specific areas. Controlled grazing can have multiple benefits including:

- reducing weed biomass, making follow up spraying more effective
- reducing weed competition with native plants
- preventing weeds from flowering and setting seed
- reducing fire risk
- providing a feed source for livestock.

Livestock should not be allowed to roam freely throughout wetlands as they can cause significant damage to native vegetation, spread weeds and dieback, foul water bodies, damage banks and cause soil erosion. Ideally, grazing should be limited to short 'crash grazing' episodes, best done during dry times so that livestock can access margins of the wetland without damaging banks or native vegetation. Livestock movement can be very effectively managed using portable electric fencing.

Pasture grasses such as kikuyu (*Pennisetum clandestinum*), couch (*Cynodon dactylon*), wild oat (*Avena fatua*) and African love grass (*Eragrostis curvula*) are palatable to most livestock so they can be very efficient at keeping them under control. However, weed seeds can be spread in manure so it may be necessary to place livestock in holding yards for a few days before moving them into other areas. Care should be exercised to ensure weed species present are not toxic to livestock (for example, cape tulip (*Moraea* spp.), Paterson's curse (*Echium plantagineum*)). Where appropriate, follow-up spraying after grazing provides for more complete weed control, particularly where grazing is intended as a short-term measure only.

Fire

The use of fire to control weeds in wetlands is generally not recommended, due to the complex behaviour and impacts of fire. Fires can cause a range of problems in wetlands, including the risk of exacerbating weed problems and endangering native plants and animals and starting underground peat fires. The use of fire requires careful consideration and a thorough understanding of the impact of fire on weed populations and wetland ecology and should only be undertaken by those with expert knowledge and the necessary authorisations.

Figure 32. After a fire, bare soil, increased light availability and nutrients in the soil provide ideal conditions for germination of weeds. Photo – T Calvert/DEC.

Inappropriate use of fire (for example, too frequent, too hot, wrong time of year) can lead to loss of habitat and native species diversity, and pose a risk to people and property (see Figure 32). Wetlands and bushland experiencing fires that are too frequent or intense can result in native species decline and the area becoming dominated by weeds. Although fire can be a useful tool in stimulating regeneration of native vegetation, not all weeds are fire sensitive and some may actually flourish after a fire. Where unplanned wildfires do occur, this can provide a window of opportunity to control a range of weeds that germinate in response to fire (as weed germination is often faster than native vegetation and therefore the weeds are easy to find and treat).

The invasion of annual grass weeds is of particular concern as increased soil nutrients, light and space availability after a fire favour their rapid germination and spread, out-competing regenerating native plants. Grasses such as perennial veldt grass (*Ehrharta calycina*) and African lovegrass (*Eragrostis curvula*) are common examples of weeds which flourish after a fire. These weeds can dramatically alter wetland vegetation composition in the long term if left unchecked.

Use of controlled managed burns (for example, spot or mosaic burns) may be appropriate under certain circumstances: for instance, in controlling large and difficult weeds such as introduced bulrush (*Typha orientalis*) or pampas grass (*Cortaderia selloana*). The aim of a controlled managed burn is to burn only the desired area in a manner that minimises damage to the environment, people and property. Weed control following fire must be vigilant in order to kill newly germinated weeds as soon as they appear. Where appropriate, follow-up spraying is a very effective as a post-fire control strategy.

Controlled burns require a permit

It is important to seek expert advice before undertaking any controlled burns in or around a wetland or property. A permit from the local government authority is required before undertaking any burning on rural properties. Many local government authorities enforce a total fire ban during the summer - early autumn period and fines are applicable if burning is undertaken at this time.

Flame and steam weeding

These methods involve the use of extreme heat to kill non-woody weeds by rupturing plant cell membranes, thus rendering the plant unable to retain moisture and causing it to die off. These methods are best suited to annual grasses and herbs. Repeat applications may be required as only the leaf/stem material is killed and the roots are left intact, meaning plants may re-sprout.

Flame weeding is done using a portable unit, usually comprising of a gas bottle (liquefied petroleum gas or propane) and hand wand. Vehicle mounted units can be used for larger jobs. A direct flame or infra-red burner is applied to the weeds using a hand wand until the plant leaves are severely wilted (not burnt). Flame weeders should be used with extreme caution in fire risk areas. Although flame weeding is not yet widely used in Australia, it has been used successfully for many decades in Europe for weed control on organic farms and on hard surfaces in urban areas.

Steaming involves delivery of pressurised heated water directly onto plant leaves using a hand wand or similar apparatus. Some local government authorities in Western Australia have used steam weeding to control weeds on road verges or footpaths, where use of chemicals is undesirable due to pedestrian use, or where the weeds occur within environmentally sensitive areas. Repeated applications may be needed, particularly on mature perennial weeds.

Although both these methods hold promise as alternatives to herbicides, more research is required to fully assess their effectiveness on a range of weed types and conditions.

Biological control

Many introduced plants that have become environmental weeds in Western Australia are not a problem in their native environment, due to the presence of natural competitors such as insects, herbivores and pathogens that keep their numbers and growth under control. **Biological control** of weeds refers to the introduction of predators or pathogens that will attack and debilitate weeds without becoming pests themselves or adversely affecting native flora and fauna, agricultural crops and livestock. The aim of biological control agents is not necessarily to eradicate a weed but to reduce its population to a more manageable level.

Biological control: the control of an introduced plant or animal by the introduction of a natural predator or pathogen, usually bacteria, viruses or insects, or by biological products such as hormones

The use of biological control agents for environmental weeds is not yet widespread due to the huge costs involved in conducting research and testing of the agent. Additionally, not all weed species are suitable for biological control. Although relatively few environmental weeds have been subject to biological control programs in Australia, examples of some that have include skeleton weed (*Chondrilla juncea*), salvinia (*Salvinia molesta*), bridal creeper (*Asparagus asparagoides*), blackberry (*Rubus ulmifolius*), cape tulip (*Moraea* spp.), water hyacinth (*Eichhornia crassipes*) and Paterson's curse (*Echium plantagineum*).

➤ For more information on biological control of weeds, contact the Department of Agriculture and Food or see www.agric.wa.gov.au.

Chemical control

In some situations, use of herbicides is the most cost-effective, practical and efficient means of controlling weeds. Herbicides can be used as the sole means of controlling weeds or in combination with other methods. Two major advantages of using herbicides are that weeds can be selectively targeted where necessary, and soil disturbance is kept to a minimum. Disadvantages of using herbicides are their toxic nature and potentially harmful effects on humans, livestock and the environment if used incorrectly. Use of herbicides around wetlands in particular needs careful consideration and care due to the risks of chemicals contaminating the water and damaging or killing aquatic life. At present, Roundup Biactive® is the only registered herbicide for use near water in Australia. If herbicides are to be used, application methods that have the least potential for damaging non-target species should be considered first, for example, cut stump, wiping or injecting instead of spraying, which has the potential for spray drift related impacts.

When using herbicides, it is essential to apply the correct herbicide, in the right dose, at the right time, using the correct application method. Use only registered herbicides, follow manufacturer's instructions on the label, and wear the appropriate protective clothing during handling. All registered herbicides are labelled with important information to assist in selecting the correct product and give the recommended application methods and dose. Labels also provide safety and poisoning information and recommended disposal methods.

extra information

Legal obligations for herbicide users

The *Pesticides Act 1999* provides for the registration of herbicides, labels and containers.

In Western Australia, anyone who uses herbicides is bound by the Health (Pesticides) Regulations 1956. These regulations were developed to provide protection for the applicator, the public and the environment from misuse of pesticides and herbicides. Herbicide labels are written in accordance with the regulations and therefore any herbicide user has a legal obligation to read and follow instructions on the label. The label provides directions for use, and for the protection of the environment, information about storage and disposal, recommendations for personal protective equipment and information about the weeds that can be treated.

Despite the provision of these details, many environmental weeds are not listed for use on herbicide labels and therefore an off-label permit may be required. The Department of Agriculture and Food has obtained a minor use off-label permit for a number of herbicides to be used specifically on environmental weeds in non-crop areas (including wetlands and bushland) until March 2017. This permit (PER13333) provides for the use (by any person in Western Australia) of a herbicide product in a manner other than that specified on the approved label of the product. However, persons who wish to use herbicide products in ways other than those specified on the approved label, must read and follow the permit instructions. For more information see www.apvma.gov.au/permits.[13]

Ideally, all herbicide users should undertake training in correct preparation, handling, application, transport and storage of herbicides. Although there is currently no legal requirement for herbicide users (other than paid contractors) to undertake training in the use of herbicides, legislation for use of chemicals is under review and this may change in the future.

Wetting agent: a substance that helps water or other liquid to spread or penetrate (also known as a surfactant or penetrant)

➤ For additional detail on herbicide use, products available, safety and environmental considerations and recommended herbicides for weeds see ‘Sources of more information’ at the end of this topic.

Use of herbicides in and around wetlands

The use of herbicides in and around wetlands should be undertaken with great caution, and only as a last resort, when non-chemical weed control methods are not realistic or viable. There is potentially a great risk to aquatic life if herbicides enter wetlands or waterways. Of particular concern is the impact of herbicides and associated **wetting agents** on frogs. Studies have shown that tadpoles and mature frogs have been found to be extremely sensitive to these chemicals, which may cause damage to their skin and gills, resulting in death (see Figure 33).

Figure 33. Frogs and tadpoles are extremely sensitive to certain herbicides and wetting agents. Seek advice from organisations such as the Department of Environment and Conservation or Department of Agriculture and Food before using herbicides in and around wetlands where frogs are present. Photo – C Mykytiuk/DEC.

Tips on reducing environmental risks associated with herbicide use near wetlands

Adapted from Cooperative Research Centre for Australian Weed Management's Introductory Weed Management Manual.[7]

- Use only herbicides that are registered for use in wetlands and/or are documented to have low toxicity to aquatic organisms (for example, Roundup Biactive®, Fusilade®).
- Apply herbicide at the recommended rate.
- Ensure that weeds are treated at the appropriate time (when surface water levels are low) to reduce the need for repeated follow-up treatments.
- Mix herbicides with a coloured dye to mark areas that have been sprayed.
- Avoid using wetting agents, as many of these are more toxic to wetland fauna than the actual herbicide.
- If contractors are to be used for herbicide application, ensure they follow procedures to minimise risks to wetland fauna.
- If possible, treat weeds close to water bodies progressively rather than in one large-scale operation, to minimise risks to wetland fauna, and to reduce erosion and habitat loss where weeds are binding the soil or providing habitat.
- Mixing of chemicals and cleaning of equipment should be done away from the wetland and in a location where any accidental run-off will not directly enter the wetland.
- Wherever possible, direct the spray away from water bodies, when there is no wind.
- When spraying around drains that feed into wetlands, move upstream when spraying rather than downstream to aid dilution of any contamination and to avoid creating a 'slug' of herbicide entering the wetland.
- Spray only when rain is not expected for several days.
- Check with the local government authority to find out what regulations apply for the application of herbicides near wetlands.

The only herbicide registered for use around wetlands at present is Roundup Biactive®, which is a broad spectrum, non-selective herbicide reported to be 100 times safer for frogs than the original Roundup formulation.[14] To minimise potential impacts on frogs, the use of herbicides should be avoided between late autumn and early spring, when egg-laying, hatching and subsequent dispersal of juvenile frogs takes place. Timing may vary between species, so it is important to seek expert advice for assistance in identifying frog species present in wetlands, and to confirm the timing and duration of their breeding cycles before herbicide application takes place.

Fusilade®, a selective grass-specific herbicide (commonly used to control annual and perennial veldt grass, kikuyu, couch and water couch) has been tested in Western Australia and found to be highly effective in removing introduced grasses. Care should be taken when using Fusilade® and the stronger preparation Fusilade Forte® in and around wetlands as recent studies have shown that it can have a negative effect on native seed germination.[15] Fusilade® is slightly soluble in water and has low toxicity to aquatic organisms. To minimise risk of negative impacts on wetland flora and fauna, always follow the manufacturers instructions on the label and apply carefully to target weeds, avoiding contact with the soil, water and non-target species as much as possible.

How herbicides work

Herbicides kill weeds by disrupting essential biochemical processes within the plant. Herbicides act in two ways, either via direct contact with plant surfaces (for example, leaves and stems) or when translocated through the plant's circulatory system. There are different types or herbicides including **selective**, **non-selective**, **residual**, **non-residual** and **pre-emergent**.

Non-synthetic herbicides

There are a number of **non-synthetic** herbicides on the market that may be effective against a range of weeds. These herbicides contain active ingredients such as pine, cinnamon and clove oils, petroleum or mineral oils, acetic and pelargonic acid or potassium salts. Many of these products such as those containing acetic acid or pelargonic acid are designed to 'burn' foliage, causing dessication of plant cells. Any herbicide, whether synthetic or non-synthetic, has a degree of risk associated with its use, and products that are marketed as non-synthetic, natural, or organic may still have the potential to cause harm to the environment, people or animals. Caution should therefore be exercised during use and instructions on the label for storage, handling, application and disposal should be strictly adhered to.

Timing

The best time to treat weeds with herbicides is when they are small, actively growing and have not yet set seed. Weeds are easier to kill and require less herbicide when they are small. The most effective translocation of herbicide throughout the plant occurs if herbicide is applied when transpiration is greatest, usually during midday on a sunny clear day, provided there is no wind which (if spraying) could carry spray drift onto non-target species. Avoid treating weeds when rain is expected or when they are under stress (for example, during extremes in temperature, drought or if they are diseased) as they will be less likely to respond to treatment. The timing of application may also depend on the objective of weed control: for example, spraying weeds early in the growing season when they are small will give native plants more chance of surviving due to reduced competition. Bulbs, corms and tubers are ideally treated when the underground storage organs are depleted; woody weeds, when they are actively growing; and perennial grasses, when they are actively growing (before flowering). However, spraying later in the growing season may make it unnecessary to follow up with treatment for late germinants or weeds that germinate following initial spraying.

Selective: have been developed to kill a particular type of plant (e.g. grasses)

Non-selective: (or broad spectrum) herbicides kill a wide range of plants

Residual: remain active in the soil for some time and may kill germinating seeds and susceptible plants

Non-residual: (or knockdowns) kill existing weeds but have no effect on germinating seeds

Pre-emergent: kills germinating seedlings when applied to the soil before germination[8]

Non-synthetic: of natural origin; not derived artificially by chemical reaction, and free from chemical treatments or additives. Other terms commonly used to describe non-synthetic herbicides include natural or organic herbicides.

Techniques for herbicide application

There are many techniques for herbicide application. Selection of the most appropriate technique will depend on a range of factors including the weed species, extent and severity of infestation to be treated, nature of associated vegetation/habitat, available equipment and resources.

Herbicide wipe

This method is ideal for areas where spraying is not suitable: for example, where weeds are growing in environmentally sensitive areas that may be adversely affected by spray drift, such as within dense native vegetation or around inundated or waterlogged areas. Herbicide is wiped or brushed onto the leaves using equipment with materials soaked in herbicide such as a wick applicator, a modified hand sprayer or glove with foam attached. This method can be time consuming in areas where infestation is severe. Care needs to be taken to ensure that herbicide does not drip from weeds onto non-target species.

Foliar spraying

Foliar spraying is a good option for controlling wetland weeds where the risk of spray drift onto native vegetation (non-target species), inundated or waterlogged areas is minimal. Spraying should only be undertaken on fine, still days to minimise risk of run-off of chemical and/or spray drift. Foliar spraying techniques include spot spraying and blanket spraying, using equipment from hand sprayers, backpack sprayers to boom sprays operated from vehicles (see Figure 34). Whichever method is chosen, it is important that the operator knows the difference between weeds species and native species, particularly in areas where native grasses could be mistaken for weeds. The site should be inspected prior to spraying to ensure familiarity with target and non-target species. It is not recommended for saplings or mature trees with thick, waxy leaves (which limits absorption of herbicide) or where it is difficult to treat the canopy without off-target damage.

Figure 34. Spot spraying weeds using a backpack and hand held applicator minimises damage to non-target species. Photo - T Schwarten/Syrinx.

➤ For additional detail on herbicide application see section in this topic on ‘Using contractors’.

Spot spraying

Using a handsprayer or backpack, this method allows selective targeting of weeds and is useful where weeds are growing in sensitive areas and more accuracy is required to avoid damage to non-target species.

Blanket spraying

Using a backpack or a boom spray operated from a vehicle is useful for treating large or dense infestations where potential for damage to off-target species is low.

case study

Challenges in wetland rehabilitation at Bibra Lake

By Denise Crosbie (Cockburn Wetlands Education Centre)
and Norm Godfrey (Wetlands Conservation Society)

Wetlands are dynamic in nature. Bibra Lake in Perth's southern suburbs experiences seasonal patterns of wetting and drying. Developing an understanding of these patterns has assisted in the development of a successful rehabilitation program at Bibra Lake.

Zoning in wetlands

Bibra Lake is a permanently inundated wetland approximately 135 hectares in size with a maximum depth of 2.5 metres. The area of the lake that is inundated fluctuates from season to season and year to year. Water levels are largely influenced by rainfall, groundwater flows and evaporation, peaking in October and falling to minimum levels during April. Different wetland plants and weeds are associated with different zones of the wetland and this has implications for rehabilitation activities (see Figure 35).

Getting started

Maps were prepared to gain a better understanding of site conditions including water levels, topography, type and extent of existing native vegetation and weeds.

Weed control

Moving from the seasonally inundated zone towards the waterlogged zone, Bibra Lake is ringed by water couch (*Paspalum distichum*), paspalum (*Paspalum dilatatum*) and kikuyu (*Pennisetum clandestinum*). Nutgrass (*Cyperus* spp.), spear thistle (*Cirsium vulgare*) and bushy starwort (*Symphotricum squamatum*) invade bare spaces amongst the grasses. Weed control has been a major task as the removal of these primary weeds creates a space for others (secondary weeds). A combination of manual and chemical control, combined with mulching and saturation planting, has been very effective (see Figure 36).

The weed control efforts at Bibra Lake provided the following learnings:

- Chemical treatment is best applied during summer when weeds are actively growing and water levels have receded.
- Roundup Biactive® has been effective for all primary and secondary weeds (no bulbous species were present).
- A staged approach has been essential because active growth of weeds is staggered as water levels recede.
- Commitment to monthly weed control has been required because weeds actively grow in waterlogged zones during periods of maximum water level, and grow in seasonally inundated zones at minimum water level.
- Weed biomass did not require slashing in the seasonally inundated zone because it decomposed during and after flooding events. It required mowing in the waterlogged zone in readiness for a planting event, as it took years to decompose.

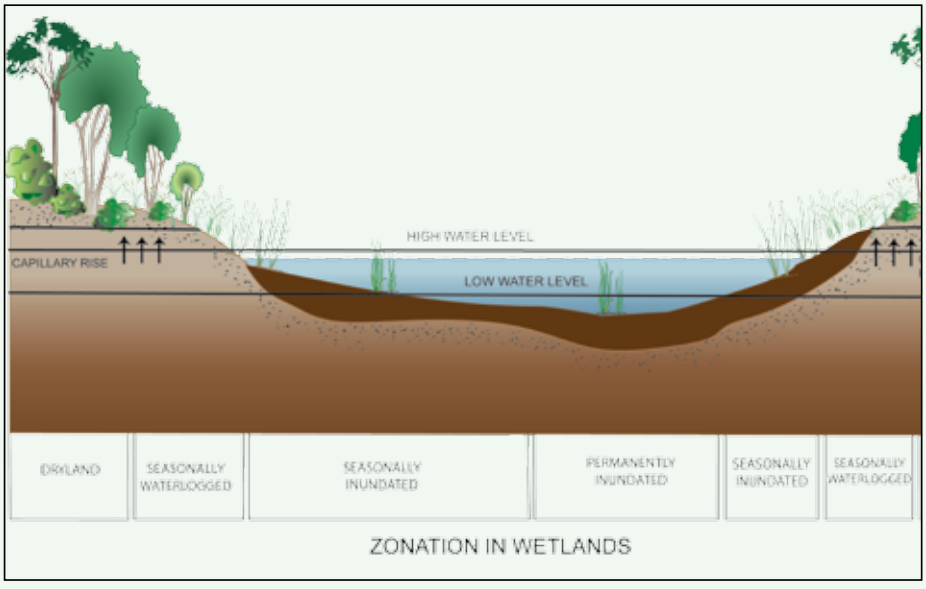


Figure 35. When controlling weeds, it is important to consider the different wetland zones and how they might influence where, when and how weed control should be undertaken. Adapted from - D Crosbie/Cockburn Wetlands Education Centre.

case study

- Mulching of the lower waterlogged to upper seasonally inundated zone with suitable mulch (the weediest zone) reduces the frequency of weed control (if using mulch, consideration should be given to dieback, weeds and nutrient input).
- Jute and paper weed matting barriers were ineffective where healthy populations of purple swamphens (*Porphyrio porphyrio*) exist.

Trials and tribulations

During the early days of rehabilitation at Bibra Lake the following problems were encountered:

- Timing of grants restricted the ability to order seedlings early and thus limited species availability.
- Chemically treated weeds did not mulch down in time for planting.
- Numerous seedlings needed replanting because they were established in the slashed weed biomass instead of the soil.
- Late plantings (September) required summer watering of the seasonally waterlogged zone.
- Secondary weed invasion was extensive.
- Planted sedges were predated by waterbirds.

Although wetland trees and tall shrubs were able to be established in weedy environments (though they grow more slowly), the object was to re-introduce understorey and attain a reasonably 'self-sustaining system' through dedicated weed control efforts.

Revegetation

Due to the dynamic nature of wetlands, many native plants may be growing outside of their optimal establishment zone. Be careful! Look at historical water data for the wetland, and at other wetland sites prior to planting. It is also difficult to predict future water levels, and during some years you may lose plants – this is part of the challenge.

Wetlands plants grow rapidly and are much quicker to reward you than their slower bushland counterparts. The planting efforts at Bibra Lake included:

- saturation planting to out-compete the weeds
- planting transitional, waterlogged and upper seasonally inundated zones during winter months
- staging planting of the lower seasonally inundated zones following a fall in water level (approximately November onwards)
- organising planting days after the maximum water levels
- removing tree guards the following winter to avoid summer predation by rabbits
- propagating locally sourced seed and establishing a wetland seed production area for future supplies.

So, can we really bring back the understorey?

Unfortunately there are no quick solutions when it comes to rehabilitation activities. The understorey is looking fantastic, bandicoot diggings are evident, and the frogs and birds are breeding. Bushy starwort, spear thistle, nutgrass and lotus invade bare areas where saturation planting has not been achieved. Our knowledge is growing and we need to continue long-term monitoring and evaluation to determine the true outcomes of our trials.

Established in 1993, the Cockburn Wetland Education Centre is an independent, not-for-profit community organisation dedicated to wetlands, restoration activities, environmental education, youth services and facility hire. Numerous volunteers implement the centre's activities along with the assistance of a small band of dedicated staff. The centre lies in the suburb of Bibra Lake, 15 kilometres south of Perth, Western Australia. It provides a gateway to Beeliar Regional Park, which contains 27 wetlands within two parallel wetland chains.

case study

Figure 36. (below) Weed control and revegetation at Bibra Lake. (a) pre-weed control, the three main grass weeds: kikuyu, paspalum and water couch; (b) the site post-spraying and preparation for revegetation; (c) post-mowing ready for planting; (d) seedlings were planted with tree guards and weed mats to help combat weed regrowth; (e) secondary weed growth – weed regrowth was less where mulch had been applied; (f) the site two years later following revegetation; (g) water couch (background) during the winter months when dormant and not actively growing. The inundated area in the foreground is where the water couch was treated the previous year and replanted with sedges; (h) water couch during the summer months when it is actively growing and the best time to spray. Photos – D Crosbie/Cockburn Wetlands Education Centre.

(a)

(b)

(c)

(d)

(e)

(f)

(g)

(h)

Stem injection

Stem injection is used to treat woody weeds such as trees and large shrubs which would be very difficult to physically remove, or those that produce suckers in response to damage to their roots or canopy. Physical removal of trees and large shrubs risks major disturbance and damage to non-target species. Stem injection involves drilling holes into the trunk or main stem, and injecting herbicide into the holes. The holes must penetrate the **sapwood tissue** to ensure that the herbicide will be transported throughout the plant. Ideally, holes should be drilled at 5–8 centimetre intervals and at a downward angle of 45 degrees to reduce the risk of spillage. Herbicide should be injected within 10 seconds of drilling to maximise uptake in the sapwood tissue (before the plant begins to 'seal' the wound and inhibit uptake).

This method allows selective treatment of individual plants with minimal risk to non-target species. Equipment used includes a cordless drill, drill bit and an injection gun or syringes for injecting the correct dose of herbicide. If a drill or injection equipment is not available, angled cuts can be made around the stem using a chisel or tomahawk (referred to as 'chipping' or 'frilling'). When using this second method, more care is required to avoid herbicide leaking from the cuts and dripping down onto the soil or other plants.

Sapwood tissue: specialised plant tissue that transports water and minerals upwards from the roots to the stem, via capillary action

Heartwood: the central, woody core of a tree, no longer serving for the conduction of water and dissolved minerals, usually denser and darker in colour than the outer sapwood

Ringbark: to completely remove a strip of bark around the trunk or main stem of a tree or shrub, causing its death

Cut and paint

This method is used for large trees or shrubs that re-sprout and involves cutting off the trunk or main stem horizontally, as close to ground level as possible. Herbicide is then painted or sprayed immediately onto the sapwood (not the **heartwood** which is inactive and will not circulate the herbicide around the plant). Equipment required to cut down woody weeds include secateurs, loppers, hand saws and chainsaws. Herbicide can be applied with a paint brush, squeeze or spray bottle, or wick wiper. If removing the cut plant material from the site, care should be taken to minimise damage to non-target species and prevent spreading seeds. This technique is not suitable for large infestations of mature trees as felling them may cause damage to surrounding native vegetation. In addition, painting the cut stems may not deliver enough herbicide to kill the rootstock.

Basal bark spraying

This method can be used to treat woody weeds such as larger trees with thin bark and small stems (less than 20 millimetres diameter): for example, saplings, regrowth and multi-stemmed shrubs and trees. Herbicides need to be oil soluble and mixed in an appropriate oil-based substance (such as diesel) and sprayed around the full circumference of the trunk or stem. Spraying should be from ground level up to 60 centimetres in height. Care should be exercised to ensure that the bark is dry and free from dirt and that the treatment solution does not drip or run off onto non-target vegetation, soils or into water bodies. This method is quicker than cut and painting or injection as it evenly distributes the herbicide throughout the sapwood.

Scrape and paint

This method is useful for vines or other creeping plants with a woody stem that cannot be injected or cut off at the stem and painted due to too small an area for herbicide uptake. It involves scraping off 20 millimetres to 1 metre of bark along the length of the stem and applying herbicide to the exposed sapwood. Stems smaller than 10 millimetres in diameter can be scraped on one side and those above 10 millimetres should be scraped on two sides. Care should be taken not to **ringbark** the stem as this will inhibit transport of herbicide throughout the plant.

If vines are tangled in amongst native vegetation, it may be best to leave them in place once they have been killed, as removing them may damage native plants.

Keeping records of herbicide use

It is important to keep records of herbicide use to monitor success of the weed control program. Details that should be recorded include:

- herbicides used
- rate of application
- weeds treated
- size of the area treated
- date and time of treatment
- method of application
- weather conditions.

This information will help determine which methods have been successful and which haven't, so that any follow-up weed treatment can be modified if required.

Integrated weed control

Integrated weed control involves the use of a combination of control methods to achieve the best results in the most cost effective and practical way. The aim of integrated weed control should be to achieve long-term weed control without damaging the environment. Integrated weed control methods should reinforce each other and, where appropriate, assist in reducing reliance on herbicides in the long term. Integrated weed control is particularly effective when used in combination with other land management methods (for example, fencing off wetlands from livestock, planting shelterbelts) that ultimately help to prevent and reduce the spread of weeds and improve the overall condition of the natural environment.

Good planning and understanding of the site conditions (for example, soil, topography, other vegetation, climate) and the life cycle and biology of weeds is essential to ensure that the various control techniques are applied in the correct manner, at the correct time(s) and reduce future effort and cost of weed control.

Summary of weed control methods

A summary of the weed control methods, their advantages and disadvantages and types of weeds they are best suited to is provided below in Table 5.

Table 5. Comparison of weed control methods (adapted from Cooperative Research Centre for Australian Weed Management, 2004)[7]

Treatment	Advantages	Disadvantages	Suitable for control of
Manual removal (hand pulling, digging etc)	• Selective • Minimises risk to surrounding plants • Supplements other techniques • Can prevent seeding and spread • Effective on small infestations • Enhances plant identification skills and familiarity with sites	• Can disturb soils if poorly done • Timing limitations, needs moist soils • Can spread weed propagules • Unsuited to large infestations • Inappropriate for some weed species and large plants • Labour intensive	• Annual grasses • Perennial grasses • Broadleaf herbs • Corms, bulbs, tubers • Aquatic weeds

Treatment	Advantages	Disadvantages	Suitable for control of
Soil cultivation and scalping	• Can eradicate weeds • Reduces nutrient loads • Removes soil-stored weed seed bank • Can aid site rehabilitation	• Non selective • Disturbs and potentially damages wetland soil values • Spreads propagules • Destroys local flora and fauna habitat • Removes soil stored local flora seed bank • Potential for erosion/run off • Expensive • Site rehabilitation required • Technical proficiency required	• Annual grasses • Broadleaf herbs
Slashing, mowing, cutting (brushcutters, mowers, slashers)	• Minimises soil disturbances • Mimimises risk to local flora • Can prevent seeding and spread • Removes excess foliage (or follow-up treatments) • Supplements other methods • Helps to weaken plants, making them susceptible to other forms of control • Inexpensive	• Usually doesn't eradicate weeds • Can prevent seeding by local flora • Can introduce/spread weed propagules • Can encourage weed growth • Can increase fuel loads (dried material)	• Annual grasses • Perennial grasses • Annual herbs
Competition strategies (direct seeding, plantings, natural recruitment)	• Suppresses weeds • Can alter light levels and nutrient-moisture availability • Restores vegetation structure • Restores floristic diversity • Enhances fauna habitat	• Altered conditions can favour weeds • Can undermine vegetation structure with inappropriate species selection • Often entails intensive management input during establishment phase • Can be labour intensive (costly) • Specialist knowledge required	• Annual grasses • Perennial grasses • Broadleaf herbs • Corms, bulbs, tubers (during flowering) • Aquatic weeds
Mulches and smothering treatments	• Inhibits/prevents weed seeding and spread • Can complement site rehabilitation • Erosion/run-off control • Aesthetics enhanced (mulches)	• Usually non-selective • Can encourage weed growth • Prevents local plant growth and spread • Can introduce weed propagules • Can alter soil chemistry • Affects soil conditions and soil microfauna • Ongoing maintenance required • Aesthetics undermined • Costly and labour intensive	• Annual grasses • Broadleaf herbs
Weed barriers	• Selective • Reduces reliance on herbicides • Supplements other methods • Can be incorporated into hard landscaping	• Constructed barriers can be expensive and labour intensive • Not suitable for large areas	• Annual grasses • Perennial grasses
Solarisation (clear or black UV plastic)	• Can be selective • Can control tenacious weeds • Inhibits/prevents seeding and spread • Supplements other methods • Appropriate on a small scale • Low costs (once installed)	• Usually non selective • Ineffectual on many weeds • Unsuitable for large infestations • Prevents local plant growth and spread • Affects soil conditions and soil micro-fauna • Ongoing maintenance require	• Annual grasses • Perennial grasses

Treatment	Advantages	Disadvantages	Suitable for control of
Fire (control burns, spot-burns)	• Removes dead and excessive foliage (for follow-up spray treatments) • Supplements other methods • Can encourage local flora regeneration • Encourages germination of soil stored weed seed bank (for follow-up treatments) • Relatively inexpensive • Can kill some weed seed banks	• Usually does not eradicate weeds • Inappropriate for non-fire adapted ecosystems • Damages native vegetation/fauna if used incorrectly • Seasonal and timing limitations • Encourages weed growth/ germination • Altered nutrient-moisture availability can favour weeds • Potential for run-off/erosion • Fauna, people, property risks • Can be costly if establishment of fire breaks and personnel to control fire are involved • Specialist knowledge required	• Not recommended in general
Flame and steam weeding	• Selective • Reduces reliance on herbicide in sensitive areas • Minimal soil disturbance • Minimal environmental impact	• Can be expensive to use • May require repeated applications • Labour intensive • Variable results • Risk of off-target damage • Risk of fire • Specialist knowledge required	• Annual grasses • Annual broadleaf
Biological controls	• Selective • Can suppress weed growth and spread • Supplements other methods • Long-term value for money • Minimal labour input (in the field) • Minimal direct environmental impacts	• Timing limitations • Variable results • Does not eliminate weeds • Other controls required • Expensive to develop • Limited range of weeds can be targeted	• Bridal creeper • Blackberry
Herbicides (foliar application)	• Selective (depending on choice of herbicide, timing, plant life cycles, operator skill) • Can prevent weeds seeding and spreading • Appropriate on small and large weed infestations • Minimises direct soil disturbances • Inexpensive	• Potential for non-selective damage/ may destroy local flora • Potential impacts on the broader environment • Technical proficiency required • Operator/public hazards	• Annual grasses • Perennial grasses • Broadleaf herbs • Corms, bulbs, tubers (at or during flowering) • Aquatic weeds
Woody weed treatments (cut and wipe, stem injection, scrape and paint etc.)	• Selective • Minimises risks to local flora • Prevents seeding and vegetative spread • Inexpensive (on small infestations)	• Site disturbances can be excessive, care is needed • Can spread weed propagules (by removal of plant material from the site) • Can destroy native fauna habitat • Can encourage weed growth/ germination • Operator/public hazards • Costly and labour intensive (on large infestations)	• Trees, large shrubs

Monitoring weed control

Monitoring is an important aspect of weed management. It helps to identify where weed control efforts have been successful (or otherwise) and where efforts may need to be continued or modified in the future. Regular monitoring (at least twice a year) will also indicate areas in which weeds are re-invading and therefore where prompt treatment is required while plants are still in the early stages of growth.

➤ For additional detail on wetland monitoring, refer to the topic 'Monitoring wetlands' in Chapter 4.

Long-term monitoring will help to finetune existing and future weed management programs and optimise the use of available resources. Weed surveys and mapping are useful ways of monitoring and recording the success of weed control measures. Taking photographs (photo points) is also a good way of recording weed mortality, regrowth and also any natural regeneration occurring after weed control.

Using contractors

When using contractors to undertake weed control, it is essential that they are trained and experienced in working in a wetland or bushland setting and will do everything necessary to ensure that weeds are not spread and environmental damage is avoided, particularly where herbicides are to be used. Spray contract businesses must be registered with the Pesticide Safety Section (PSS) of the Health Department of Western Australia.

Spray contractors must be able to tell the difference between weeds and native plants and be prepared to use equipment that minimises the risk of off-target damage (for example, use of backpacks or other hand-held sprayers or wiping devices). They should also be familiar with the risks of herbicide use near wetlands and understand the most appropriate chemicals and application rates for the target weed species.

It is helpful to provide contractors with a weed map and a guided site visit to ensure that they know the exact location of weeds to be controlled, their relationship with native vegetation and how to access those areas. They should also follow standard hygiene practices to avoid spreading seed and dieback to and from the site, e.g. by cleaning tools, equipment, machinery, vehicles (especially tyres) and boots appropriately.

Whether or not to manage weeds in a wetland

When deciding whether or not to manage weeds in wetlands, there are a number of factors that should be considered including: the biodiversity and other value(s) under threat; how practical and effective management will be; and the amount and availability of resources to undertake management (time, money and labour). As resources for weed control tend to be limited it is also important to consider the impact and invasiveness of various species and their current distribution. There may be a number of weed species present in or around a wetland and available resources may mean that not all of them can be dealt with. Therefore, priorities for control may be weeds with the greatest potential for rapid spread and environmental damage, for which effective control is achievable.

Some questions to help focus the decision-making process include:

- **Is the weed a declared plant species or a weed of national significance (WONS)?**

  Landholders are obliged to control these plants at their own expense. Declared plants and WONS can cause significant damage to ecosystems and agricultural productivity if not controlled. Early intervention provides the best chance of preventing long-term damage to wetlands.

- **Do the weeds pose a fire hazard?**

  Weeds that present a fire hazard should be controlled as a matter of priority. The impacts of a fire are far-reaching and can not only damage wetlands, they can also put human lives and infrastructure at risk.

- **Are the weeds inhibiting native plant growth and/or regeneration?**

  If weeds are preventing the growth or regeneration of native vegetation, it is likely that the vegetation structure of the wetland is becoming degraded and biodiversity values reduced. Over time, if weeds are allowed to dominate the understorey, the wetland will have reduced biodiversity value, and the scale of the weed problem may become unmanageable.

- **Are the weeds degrading native fauna habitat?**

  If habitat for native fauna is degraded by weeds, the decline in habitat diversity will reduce the biodiversity of the wetland. In cases where weeds provide some fauna habitat (for example, introduced bulrush can provide waterbird habitat), removal should be gradual to allow fauna time to adapt until natural regeneration (or revegetation) occurs.

- **Are any threatened fauna, declared rare flora (DRF) or threatened ecological communities (TECs) present?**

  Under the *Wildlife Conservation Act 1950*, individual species of plants and animals are protected, with the level of protection varying depending on whether the species is rare or endangered. Weeds can pose a threat to these values by altering vegetation structure and diversity and degrading fauna habitat. Landholders with identified threatened fauna, DRF or TECs on their land should contact the Department of Environment and Conservation before undertaking weed control or any other activity that has to potential to negatively impact on protected species.

  ➤ For additional detail on DRF and TECs see the topic 'Wetland vegetation and flora' in Chapter 2.

- **Are the weeds a potential threat to other values?**

  The potential for weeds to threaten other values both within and outside the wetland or property boundaries should be considered. For example, aesthetic and/or real estate values may be compromised, health problems may occur (for example, pollen or grass seeds causing allergies in humans, pets or livestock), or there may be the potential for weeds to spread into adjacent properties or wetlands.

Topic summary

- Weeds can be defined as 'plants that become established in natural ecosystems, altering natural processes and leading to the decline of the communities they invade.'[3,1]
- Weeds threaten primary production, and the biodiversity and conservation values of Western Australian ecosystems. They affect severely on agriculture and biodiversity by competing with crops and out-competing native plants and degrading habitat.
- Weeds respond rapidly to disturbance, out-competing native plants for available light, water, space and nutrients. They also have fewer natural predators, pests or diseases than native plants, which assists them to grow and spread virtually unchecked.
- Weeds tend to invade areas where disturbance of soil or natural vegetation has occurred or where the natural fire regimes have changed. Activities that disturb natural areas such as clearing native vegetation for agriculture, settlement and transport, logging, rubbish dumping and livestock and vehicle movement contribute to the introduction and spread of weeds.
- Wetlands are particularly vulnerable to weed invasion where moist productive soils are present in association with disturbance factors, Phytophthora dieback and altered fire regimes.

- Understanding the life cycle and biology of weeds is essential for successful management.
- Weed management does not necessarily imply complete and permanent removal of every single weed in a given area. In many cases, complete removal of weeds is not desirable or feasible for many reasons – for example limited resources, increased potential for erosion or other adverse environmental impacts.
- Guiding principles for successful weed control include preventing weeds from becoming established in the first instance, accurately identifying weed species, mapping weeds and native vegetation, controlling weeds while in the early stages of growth (and before seed set), working from the least affected areas towards the worst affected areas using a combination of methods if possible, and hygiene management to avoid spreading weeds.
- Integrated weed management combines a number of weed control strategies to ensure the best possible result and most cost effective use of resources.
- Natural regeneration or revegetation should occur following weed control to minimise new weed invasions.
- Monitoring and recording the progress of weed control is essential to determine what has worked, what hasn't worked and how future weed control is best undertaken.
- When deciding whether or not to manage weeds in wetlands, a number of factors should be considered such as: impacts, invasiveness and current/potential distribution; the biodiversity and other value(s) under threat from both the weeds themselves and proposed control strategies; how practical and effective management will be; and the amount and availability of resources to undertake management over the timeframe necessary to achieve desired outcomes.

Sources of more information on managing weeds in wetlands

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Useful websites

Australian Pesticides and Veterinary Medicines Authority (APVMA)
www.apvma.gov.au
Herbicide registration information

Commonwealth Department of Sustainability, Environment, Water, Population and Communities
www.weeds.gov.au

Council of Australasian Weed Societies (CAWS)
www.caws.org.au

CSIRO Entomology (weed ecology and biological control)
www.csiro.au/science/InvasivePlants.html

Department of Agriculture and Food
www.agric.wa.gov.au
Declared Plants and their control, State Weed Plan for WA, Permitted and Prohibited species lists

Department of Environment and Conservation
www.dec.wa.gov.au/content/category/31/936/2275/
FloraBase, Urban Nature

Department of Water
http://portal.water.wa.gov.au/portal/page/portal/WaterQuality/Publications/WaterNotes?pAP=WaterManagement&pAS=Waterways
Water notes: advisory notes on river and wetland restoration

Environmental Weeds Action Network of WA (Inc.)
www.environmentalweedsactionnetwork.org.au

Global Compendium of Weeds
www.hear.org/gcw

HerbiGuide
www.herbiguide.com.au
Herbicide, weed and control information

Northern Australian Quarantine Strategy (NAQS)
www.aqis.gov.au/naqs
Target list of weeds

RG & FJ Richardson
www.weedinfo.com.au
Publishers

Weedbuster Week
www.weedbusterweek.info.au

Weeds Australia
www.weeds.org.au

Weeds Society of WA (Inc.)
www.wswa.org.au

Glossary

Annual: a plant that normally completes its life cycle (from germination to flowering, seed production and death of vegetative parts) within a single growing season

Aquatic plants: a plant that grows for some period of time in inundated conditions and depends on inundation to grow and, where applicable, flower

Biennial: a plant that normally completes its life cycle (from germination to flowering, seed production and death of vegetative parts) within two years

Biological control: the control of an introduced plant or animal by the introduction of a natural predator or pathogen, usually bacteria, viruses or insects, or by biological products such as hormones

Bioregion: a territory defined by a combination of biological, social and geographic criteria rather than by geopolitical considerations; generally, a system of related, interconnected ecosystems[1]

Broadleaf: plants that possess relatively broad flat leaves rather than needle-like leaves

Corms, bulbs, tubers: specialised underground fleshy storage organs that allow plants to flourish in nutrient deficient soils or to die back and enter a state of dormancy when conditions are extreme, such as during fire or drought[8]

Crown: the region of compressed stem tissue from which new shoots are produced, generally found near the surface of the soil

Cultivation: methods of breaking up and turning the soil

Disturbance opportunists: responding positively and rapidly to habitat disturbance

Ecosystem services: the processes by which the environment produces resources that provide benefits to humans, for example, flood and disease control, clean air, waste recycling, plant pollination[2]

Emergent: a plant that is protruding above the surface of the water or, where a water column is not present, above the wetland soils (as distinct from floating or submerged plants)

Environmental weeds: plants that become established in natural ecosystems, altering natural processes and leading to the decline of the communities they invade[3,1]

Heartwood: the central, woody core of a tree, no longer serving for the conduction of water and dissolved minerals, usually denser and darker in colour than the outer sapwood

Indigenous: a species that occurs at a place within its historically known natural range and that forms part of the natural biodiversity of a place

Life form: the shape or appearance of a plant that mostly reflects inherited or genetic influences

Local provenance: indigenous plants propagated from collections from locations as close as geographically (in terms of habitat) practicable to the location where the propagated plants are to be planted, ensuring that genetic integrity is maintained

Naturalised: plants that spread and persist outside of their normal range of distribution

Non-residual herbicides: (or knockdowns) herbicides that kill existing weeds but have no effect on germinating seeds

Non-selective herbicide: (or broad spectrum) herbicides that kill a wide range of plants

Non-synthetic: of natural origin; not derived artificially by chemical reaction, and free from chemical treatments or additives. Other terms commonly used to describe non-synthetic herbicides include natural or organic herbicides

Non-woody weeds: weeds with a non-woody green stem

Perennial: a plant that normally completes its life cycle (from germination to flowering, seed production and death of vegetative parts) in two or more growing seasons

Photosynthesis: the process in which plants, algae and some bacteria use the energy of sunlight to convert water and carbon dioxide into carbohydrates they need for growth and oxygen

Pre-emergent herbicides: herbicides that kill germinating seedlings when applied to the soil before germination[8]

Residual herbicides: herbicides that remain active in the soil for some time and may kill germinating seeds and susceptible plants

Rhizomes: stems that are buried underground

Ringbark: to completely remove a strip of bark around the trunk or main stem of a tree or shrub, causing its death

Sapwood tissue: specialised plant tissue that transports water and minerals upwards from the roots to the stem, via capillary action

Scalping: involves slicing off the top layer of soil which contains weeds and weed seeds, leaving the surface bare in preparation for revegetation

Sedge: tufted or spreading plant from the families Cyperaceae, Centrolepidaceae, Hydatellaceae, Juncaginaceae, Restionaceae, Juncaceae, Typhaceae and Xyridaceae. In these plants the leaf sheath is generally not split, there is no ligule, the leaf is not always flat and there is an extended internode below inflorescence. Some sedges are also known as rushes.

Seed dispersal mechanisms: the means by which plants distribute their seeds, for example via wind, water, birds and insects etc

Selective herbicide: refers to herbicides that have been developed to kill a particular type of plant (for example, grasses)

Shelterbelts: belts or rows of trees and shrubs planted to provide protection against prevailing winds

Stolons: stems that usually run horizontally along the soil surface

Succulent: plants which have specialised fleshy, soft and juicy tissues designed for the conservation of water, for example, cacti

Vegetative reproduction: a type of asexual reproduction found in plants. It is also called vegetative propagation or vegetative multiplication

Weed: a plant that requires some form of action to reduce its harmful effects on the economy, the environment, human health and amenity, and [the term weed] can include plants from other countries or other regions in Australia or Western Australia[2]

Wetting agent: a substance that helps water or other liquid to spread or penetrate (also known as a surfactant or penetrant)

Woody weeds: perennial weeds with woody stems including shrubs, trees and some vines

Personal communications

Name	Date	Position	Organisation
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