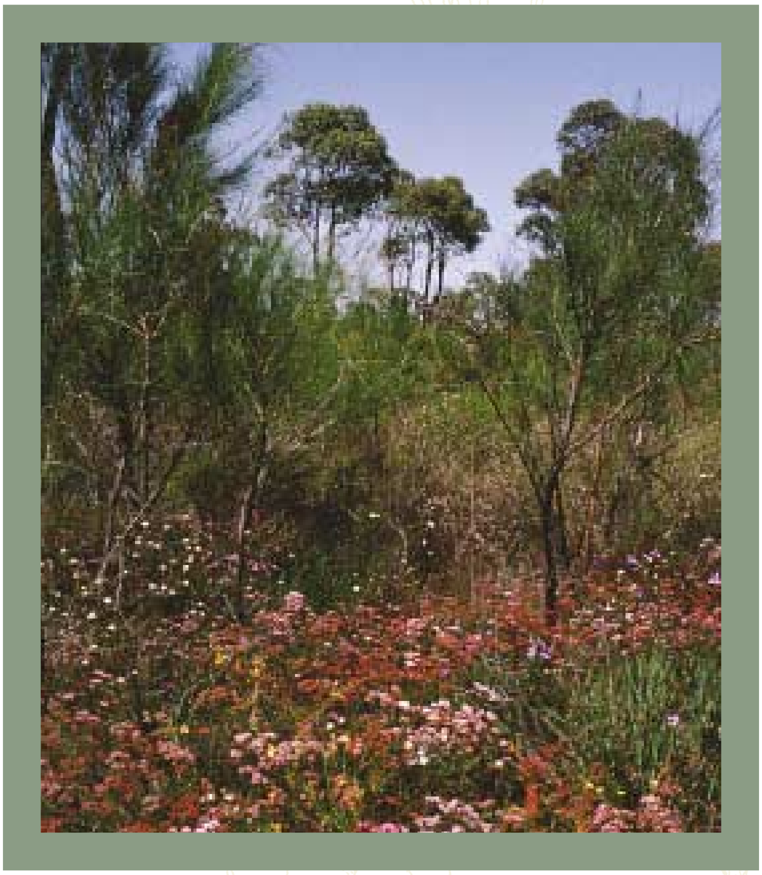
Bushland Weeds

A practical guide to their management

With case studies from the Swan Coastal Plain and beyond



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Illustrated by Libby Sandiford

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Cover photograph by Kate Brown – Late spring in the shrublands at Brixton Street Wetlands with Pink Feather Flower (*Verticordia densiflora*), Kunzea (*Kunzea micrantha*) and Purple Flag (*Patersonia* aff. *occidentalis*) in full flower.
Cover illustrations by Libby Sandiford – Some of the weeds starting to invade the Wetlands: From left to right; Harlequin Flower (*Sparaxis bulbifera*), Black Flag (*Ferraria crispa*), African Lovegrass (*Eragrostis curvula*) and Perennial Veldgrass (*Ehrharta calycina*).

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Production of the manual has been a collective effort. Kate Brown wrote the chapters on the project, managing weeds in bushland, the geophyte weeds, the other herbaceous weeds and with Kris Brooks, the mapping guidelines. Kris Brooks wrote the grasses, the woody weeds and the herbicides in bushland chapters. The maps were compiled by Kris Brooks and Kate Brown.

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Kate Brown and Kris Brooks

September 2002.

All illustrations are by Libby Sandiford and all photographs by Kate Brown, unless otherwise noted.

The Environmental Weeds Action Network (EWAN) is a community group formed in 1996 to:

- Promote understanding of the threat of environmental weeds to bushland.
- Provide information about weed control in native vegetation.
- Convince governments at all levels of the need for appropriate legislation and funding for weed control.
- Encourage research into methods of weed control.
- Encourage community participation.

WEEDS OR WILDFLOWERS

Environmental Weeds Action Network (WA) Inc.

Natural Heritage Trust

Swan Avon INTEGRATED CATCHMENT MANAGEMENT

CRC Weed management

Lotteries Western Australia Millions Won. Thousands Helped.

Contents

Introduction

The Banksia, Tuart and Jarrah woodlands, the shrublands and the species-rich heathlands of the Swan Coastal Plain and Darling Plateau are wonderful places. They contribute to Perth's unique natural landscapes, provide a window into the natural world, habitat for native fauna and support an extraordinarily diverse flora. They are fast disappearing though, mostly under urban development. Those bushlands that remain face a range of threats; one of the most serious is invasion by environmental weeds.

The concept of environmental weeds is still relatively new. Although the weediness of plants like Bridal Creeper and Watsonia have become entrenched in the public psyche, there is some way to go before the wider community accepts the extent of the problem. For example, Harlequin Flower (*Sparaxis bulbifera*) threatens one of the last remaining clay-based wetlands on the eastern side of the coastal plain and yet the species was available this year from a fundraising catalogue in at least one local primary school. Still, it is evident that many people do recognise the threats. Increasingly, community volunteers and state and local governments are involved in on-ground actions to protect bushland from the impacts of environmental weeds.

With few resources available, maximising the positive outcomes of these professional and voluntary efforts is critical. For those working on the ground, information on identification and control is available from a number of good books: Managing Perth's Bushlands (Scheltema and Harris 1995), Southern Weeds and their control (Moore and Wheeler 2002), Bush Invaders of South-East Australia (Muyt 2001), Western Weeds. A guide to the weeds of Western Australia (Hussey *et al*. 1997) and Environmental weeds: a field guide for SE Australia (Blood 2001). Importantly, this kind of information needs to be taken and applied in the context of particular bushland areas. There are no simple formulas and effective management begins with an understanding and a knowledge of each site.

It was with this in mind that, in 1998, the Environmental Weeds Action Network (EWAN), with funding from the Natural Heritage Trust, employed a project officer to work with community volunteers and local and state government land managers at bushland sites across Perth's Swan Coastal Plain. The underlying objective was to help the various land managers to develop strategies for effective weed management in their bushlands. This manual has grown out of that project.

The aim of the manual is firstly to bring together information on the biology and known control methods for the serious weeds of bushlands of the Swan Coastal Plain and Jarrah Forest. Secondly, it is to illustrate, with examples and case studies, how this sort of information can be used to manage weeds in the context of particular sites. Hopefully this will provide the reader with the basic knowledge and the framework needed to begin effectively managing the weeds in their own bushlands.

Chapter one provides descriptions of bushlands from where the case studies and examples throughout the text are drawn. Chapter two covers some general principles that should guide weed management in bushland, including the kind of area-specific information required before setting weed management priorities. The next four chapters each cover a different group or lifeform of weeds. The first three groups are all herbs – green non-woody plants: Chapter three covers the grasses, chapter four herbs that die back to corms, bulbs or tubers over summer (geophytes) and chapter five broadleaf herbs, sedges and succulents. The final group, chapter six, includes all the woody plants and a few climbers that are technically herbs, but have control strategies in common with woody climbers.

Individual chapters look at the general biology of each weed group and how it relates to dispersal, spread, control and management. Case studies examine control of certain species at particular sites and discuss the management approach taken. They often describe the set-up of trials and monitoring programs. Each weed group has a corresponding table containing a summary of information, gathered from a wide range of sources, on the biology and control of weeds occurring in bushland of the Swan Coastal Plain and Jarrah Forest. The list is based on 'A Checklist of the naturalised vascular plants of Western Australia' (Keighery 1999a) and includes species that can have an impact on biodiversity and hamper restoration and regeneration efforts. Finally there are chapters on how to map weed populations in urban bushland, an integral part of weed management and on the issues arising from the use of herbicides in bushland.

Ideally, this manual will impart enough information for the reader to devise a strategy for management of their serious bushland weeds. At the same time the authors want to highlight the complexities involved in working in Perth's bushlands; diverse and wonderful places to get to know and understand. The following chapter provides detailed descriptions of some of those bushlands along with the serious weeds that threaten them and the people who are managing them.

Chapter 1 The Project

Over four years, project officers have been involved in work at a series of bushlands across the Swan Coastal Plain and one in Western Australian Wheatbelt. The major task over that time has been to work on site with those involved in weed management and bush regeneration, providing both on-ground and technical support. The idea was to select a series of sites that were representative of bushlands on a range of soils and land forms across the coastal plain, had regionally significant conservation values and were managed by people actively involved in on-ground works.

The underlying objective has been to work with the bushland 'managers', whoever they were, to help them protect their bushland through carefully targeted and strategic weed management. Initially work involved identifying those weeds that were the greatest threats to the conservation values of each site, then mapping their distribution across the bushland. The greatest efforts have been directed to consistent management of these locally serious weeds, taking an integrated approach, addressing the causes of invasion and implementing a range of control strategies. Often trials had to be carried out to determine practical and effective methods. Project officers regularly worked alongside Friends groups, council bushland workers, and others who carried out on-ground works. Sometimes they facilitated the employment of contractors and often worked alongside them, supervising and guiding their work. At all sites monitoring was put in place to measure the effectiveness of control programs and the regeneration of native plant communities over time. For most bushlands, field herbaria of all weeds and some native species commonly mistaken for weeds were compiled.

Funding and administration

The project was funded through the Natural Heritage Trust and managed and administered by a voluntary steering committee made up of members of the Environmental Weeds Action Network (EWAN): Bob Dixon from Kings Park and Botanic Garden, Gary Matthews community volunteer and EWAN treasurer, Margo O'Byrne from the Department of Environmental Protection and Rod Randall from the Western Australian Department of Agriculture.

The sites

Shenton Bushland

Shenton Bushland, a 21 hectare remnant of Banksia (*Banksia menziesii, B. attenuata*), Jarrah (*Eucalyptus marginata*) woodlands lies on Spearwood dunes approximately eight kilometres west of the centre of Perth. With only 18 % of the vegetation complex remaining uncleared the bushland is considered regionally significant (Government of Western Australia 2000). These species-rich woodlands occur on pale yellow to grey calcareous sands derived from Tamala limestone. Rich in perennial herbs, Milkmaids (*Burchardia congesta*), Vanilla Lily (*Sowerbaea laxiflora*), Leafy Sundew (*Drosera stolonifera*), Yellow Autumn Lily (*Tricoryne elatior*) and the sedge *Mesomelaena pseudostygia* are common. The open sandy patches are often colonised by annual herbs such as Slender Podolepis (*Podolepis gracilis*) and after fire the annual grass, *Austrostipa compressa* is noticeable, flowering and seeding prolifically. Commonly occurring shrubs include Hairy Yellow Pea (*Gompholobium tomentosum*), *Daviesia nudiflora* and Grass Tree (*Xanthorrhoea preissii*). Around 120 species of natives (Marshall unpubl.) and 65 species of weeds (Brown and Brooks unpubl.) have been recorded. Approximately 50 % of the bushland is in good to excellent condition. The remainder varies from good to degraded with areas of severe localised disturbance (Ecoscape 1994, Government of Western Australia 2000).

Weeds that threaten the undisturbed bushland include a number of South African geophytes (plants that die back to bulbs, corms or tubers each year), including Yellow Soldier (*Lachenalia reflexa*), Freesia (*Freesia alba* x *leichtlinii*), Watsonia (*Watsonia meriana*) and Black Flag (*Ferraria crispa*). The perennial herbs Geraldton Carnation Weed (*Euphorbia terracina*) and Rose Pelargonium (*Pelargonium capitatum*) are serious invaders and many weedy annuals are common, particularly in the highly disturbed areas. These include Flat Weed (*Hypochaeris glabra*), Ursinia (*Ursinia anthemoides*), French Catchfly (*Silene gallica*), and Slender Suckling Clover (*Trifolium dubium*). Perennial Veldgrass (*Ehrharta calycina*) is one of the most serious invaders of the bushland often establishing in previously intact areas following fire.

For the last nine years on-ground management of Shenton Bushland has been carried out by The Friends of Shenton Bushland (Inc.), a community group formed after the bushland was saved from development in 1993. In 2000, following lobbying from community groups, a bushcare officer was employed to carry out on-ground management of bushlands within the City of Nedlands, including Shenton Bushland. In the past, much of the funding has come from government grants to the Friends. In recent times, however, the City of Nedlands has started to fund the continuation of works programs initiated through grant money. The Friends have a high level of input into management through organisation of works programs and supervision of contractors who do much of the weed management work.

Friends of Shenton Bushland and volunteers hand-weeding Yellow Soldier in the Banksia woodland.

Blue Gum Lake Reserve

Blue Gum Lake is part of a chain of wetlands that lie on the interface of the Bassendean and Spearwood dune systems. Flooded Gum (*Eucalyptus rudis*) – Swamp Banksia (*Banksia littoralis*) woodlands fringe the lake while *Banksia attenuata, B. menziesii* and *B. ilicifolia* woodlands occupy the drier uplands. Common in the understorey of the woodlands around the lake are *Centella asiatica* and Pale Rush (*Juncus pallidus*). The drier Banksia woodlands of the uplands are very species-rich, particularly in perennial herbs and shrubs. *Phlebocarya ciliata,* Prickly Conostylis (*Conostylis aculeata*) and Purple Flag (*Patersonia occidentalis*) are among the commonly occurring herbs and typical shrubs include Devils Pins (*Hovea pungens*), Rose Banjine (*Pimelea rosea*) and Pineapple Bush (*Dasypogon bromeliifolius*). The perennial native grass *Microlaena stipoides* occurs occasionally in the bushland and after fire the annual grass, *Austrostipa compressa*, is very common. Around 62 species of natives (City of Melville 1992) and 80 species of weeds (Brown and Brooks unpubl. data) have been recorded. Weed invasion is a major threat with around 40 % of the bushland suffering from severe disturbance.

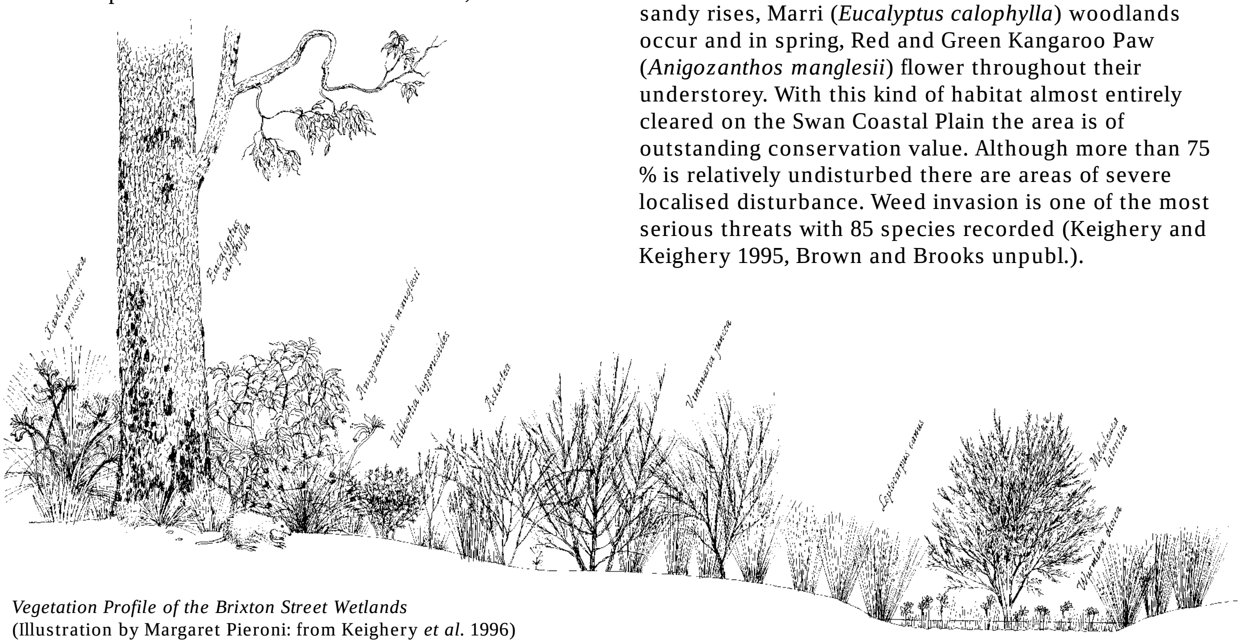
Serious weeds of the drier Banksia woodlands include Perennial Veldgrass and South African geophytes such as Freesia, Yellow Soldier and Black Flag. The Sydney Golden Wattle (*Acacia longifolia*) is a major weed of the fringing vegetation, as is Vasey Grass (*Paspalum urvillei*) and Kikuyu (*Pennisetum clandestinum*). One of the serious weed problems at the reserve has arisen from plantings of non-local species around and through the bushland. Many, including Sydney Golden Wattle, *Melaleuca leariifolia,* River Red Gum (*Eucalyptus camaldulensis*) and Geraldton Wax (*Chamelaucium uncinatum*) have become naturalised in the bushland. Additional to this threat is the planting of species that occur naturally in the bushland but have been grown from seed collected a long way from the reserve. The early flowering shrub-form of *Banksia menziesii,* from the sand plains 200km to the north of Perth, has been planted in the reserve. It makes a disturbing contrast to the later flowering form, a beautiful woodland tree that grows naturally around Blue Gum Lake. These plantings threaten the nature conservation values of the bushland as much as any South African invader.

The Friends of Blue Gum Lake have played a major role in managing the bushland for many years. They are not an incorporated group and, accordingly, acquiring government grants is difficult. The little funding that is available for weed management work comes from the City of Melville. The City has two staff dedicated to on-ground bushland management activities. Their work is spread across the City's many reserves. For herbicide spraying the City is often obliged to use 'preferred contractors'.

Brixton Street Wetlands

The Brixton Street Wetlands lie 20 kilometres south east of Perth at the foot of the Darling Scarp. A small remnant (19 hectares) on the winter-wet flats of Guildford formation clays, the wetlands support many rare and restricted plant species as well as threatened plant communities. They also support an exceedingly diverse flora of 307 native taxa (Keighery and Keighery 1995).

Most of the wetland soils are waterlogged through the winter months and deep pools form in clay depressions. When the pools are full they support a number of native aquatic plants but as water levels start to drop a series of annual and perennial herbs grow and flower. In late winter Flannel Flowers (*Tribonanthes* species), Blue Squill (*Chamaescilla* species) and Early Nancy (*Wurmbea dioica*) are flowering and by late spring Swamp Wallaby Grass (*Amphibromus nervosus*) is in abundance. By early summer the pools are dry and the claypans covered in Sundews (*Drosera* species) and Trigger Plants (*Stylidium* species). Slightly higher in the landscape, the flats surrounding the claypans also support a diverse range of native herbs, sedges and rushes. Shrubs, including Swish Bush (*Viminaria juncea*) and Feather Flowers (*Verticordia* species), are also common. On the sandy rises, Marri (*Eucalyptus calophylla*) woodlands occur and in spring, Red and Green Kangaroo Paw (*Anigozanthos manglesii*) flower throughout their understorey. With this kind of habitat almost entirely cleared on the Swan Coastal Plain the area is of outstanding conservation value. Although more than 75 % is relatively undisturbed there are areas of severe localised disturbance. Weed invasion is one of the most serious threats with 85 species recorded (Keighery and Keighery 1995, Brown and Brooks unpubl.).



Vegetation Profile of the Brixton Street Wetlands
(Illustration by Margaret Pieroni: from Keighery *et al.* 1996)

The most serious threats to plant communities across the wetlands are South African geophytes. Harlequin Flower (*Sparaxis bulbifera*) in particular is present on the edges of the claypans, throughout the wet flats and up into the Marri woodlands. It produces vast amounts of viable seed that germinate each year. Other South African geophytes that threaten the wetland flora include *Watsonia* species, One Leaf Cape Tulip (*Moraea flaccida*), Babiana (*Babiana angustifolia*), Wavy Gladiolus (*Gladiolus undulatus*) and Freesia. The South African grass *Tribolium uniolae* is a relatively recent invader but frequent fire in wetlands appears to be facilitating its movement into otherwise undisturbed areas. Annual weeds are prolific around the disturbed edges. The annual sedge *Isolepis hystrix* is a particularly serious weed forming dense mats in low-lying wetter areas.

Most of the on-ground management at Brixton Street is carried out by the Friends of Brixton Street Wetlands; a community group formed to save the wetlands from housing development in the early 1990s. The land is still vested in the state housing authority, Homeswest, and has been due to transfer to the Department of Conservation and Land Management (DCLM) for the last nine years. Management guidelines for the wetlands have been produced by the Wildflower Society of Western Australia (Inc.) with financial assistance from a Community Conservation grant (Keighery and Keighery 1995). DCLM plays some role in management as the area supports rare flora and threatened plant communities. A management group with representatives from the Friends, the Wildflower Society, DCLM, and the City of Gosnells meets on an irregular basis.

Funding for weed management and bush regeneration work in recent years has come from the Perth Branch of the Wildflower Society, DCLM and the City of Gosnells.

Elizabeth Buters, Friends of Brixton Street Wetlands.

Talbot Road Bushland

Talbot Road Bushland, a 95 hectare remnant, lies at the foot of Darling Scarp on the soils of the Ridgehill Shelf. Marri, Jarrah and Wandoo (*Eucalyptus wandoo*) woodlands occur on the heavier soils and Banksia woodlands and shrublands on the sandier soils. The woodlands support an exceedingly diverse understorey of shrubs, herbs and sedges. Around 366 taxa, many of them rare or restricted, occur across the bushland. It is the most significant area of Ridgehill Shelf vegetation remaining and the floristic communities are considered critically endangered (Keighery and Keighery 1993, Government of Western Australia 2000). Around 90 % of the bushland is in good to excellent condition but there are areas of severe localised disturbance - around drains, paths and a gravel pit. Around 55 species of weeds occur in the bushland (Brown and Brooks unpubl.).

The most widespread serious weed in the Talbot Road Bushland is the South African geophyte *Hesperantha falcata*. It occurs along path edges throughout the reserve, moving into undisturbed bushland on the heavier soils. Other South African geophytes are still quite localised in their distribution. These include Freesia, Babiana and Watsonia species. South African grasses are the other group of serious weeds with Perennial Veldgrass widespread on the sandier soils and African Lovegrass (*Eragrostis curvula*) occurring across disturbed areas of the bushland.

Talbot Road is vested in the City of Swan and managed by a committee made up of representatives from the Friends of Talbot Road, the Department of Environmental Protection, DCLM and the City of Swan. Much of the on-ground management is carried out by the Friends with DCLM and the City of Swan playing a significant role. A Natural Heritage Trust grant to the management group to implement a management plan (Environs Consulting 1999) has provided consistent funding for weed management work over the last three years.

Green Corps team hand-removing isolated plants of Perennial Veldgrass from along paths in Talbot Road Bushland.

Gingin Brook

The Gingin Brook, 150 kilometres north of Perth, is fed by perennial springs arising from the hills north east of the Gingin townsite. One of the last remaining patches of fringing vegetation left along the brook where it crosses the heavier soils at the base of the Dandaragan Plateau is located in the townsite. For two kilometres along the brook, Flooded Gum and Swamp Paperbark (*Melaleuca rhaphiophylla*) form a dense canopy over an understorey of native herbs, rushes, sedges and ferns. The herbs, *Centella asiatica*, *Persicaria salicifolia* and *Cotula coronopifolia* form ground cover in the wetter areas while Tassel Sedge (*Carex fasciculata*), Tall Sedge (*Carex appressa*) and the fern, *Cyclosorus interruptus*, dominate the understorey.

Both Arum Lily (*Zantedeschia aethiopica*) and Taro (*Colocasia esculenta*) form dense monocultures in different parts of the fringing vegetation. Two exotic pasture grasses, Para Grass (*Urochloa mutica*) and Reed Sweet Grass (*Glyceria maxima*) have also become naturalised, smothering all native vegetation where they invade. In places woody weeds such as Edible Fig (*Ficus carica*) and Brazilian Pepper (*Schinus terebinthifolius*) are displacing the native Paperbarks and Flooded Gums.

The Friends of Gingin Brook, working closely with the Shire of Gingin, have been responsible for all restoration works carried out. In 1998 with support from the shire, they received a grant from the Natural Heritage Trust to restore the fringing vegetation in the town site. They have carried out much of the on-ground works themselves, sometimes employing contractors to assist them with weed management. Green Corps teams have made a major contribution to the labour force over the life of the project.

Pauline Diggins, Friends of Gingin Brook.

Quairading Nature Reserve

The Quairading Nature Reserve is a 527 hectare crown reserve, located 164 kilometres east of Perth in the Western Australian Wheatbelt. The diverse landscape and soils of the reserve support a range of woodlands and shrublands. Salmon Gum (*Eucalyptus salmonophloia*) and Wandoo woodlands cover the valley floors, Acorn Banksia (*Banksia prionotes*) and Sand Plain Woody Pear (*Xylomelum angustifolium*) woodlands cover the deep yellow sands while a series of shrublands occur on sands and gravel soils (Keighery *et al.* 2001). Project work at Quairading was based in the York Gum (*Eucalyptus loxophleba*) – Jam (*Acacia acuminata*) woodlands that occur on the fertile brown loams associated with the granites. These woodlands support a rich annual flora. Through spring Pink Sunray (*Rhodanthe manglesii*), Pink Everlasting (*Lawrencella rosea*) and Golden Waitzia (*Waitzia nitida*) carpet the ground. Later in the season Orange Immortelle (*Waitzia acuminata* var. *acuminata*) and flowering perennial grasses such as *Aristida contorta* and *Austrostipa* species are noticeable. Shrubs are uncommon in the understorey.

The vegetation across the reserve is mostly in excellent condition with only a few serious weeds present. Around an old settlement, in the Wandoo woodland, there are a few isolated populations of Freesia, and One Leaf Cape Tulip is starting to move down creek lines. In other parts of the reserve a range of annual weeds occur around old carcass dumps, rabbit warrens, areas of nutrient run-off from adjoining farmland and along tracks. Wild Oat (*Avena barbata*) and Blowfly Grass (*Briza maxima*) are the most widespread weeds across the reserve and can be found on the more fertile soils of the York Gum – Jam woodlands, invading the understorey and displacing the rich annual flora.

The Quairading Shire has had a temporary vesting of the reserve for the last five years (1998-2002). There is a reserve management committee with representation from the Shire, the Quairading District High School, the Land Care District Committee, Rotary, Rural Youth, the Golf Club and the Tidy Town Committee. There are few on-ground resources allocated to weed management or bushland restoration. The work carried out in the reserve was in conjunction with local farmers, local Landcare Coordinators and the District High School. A workshop was held in the reserve in August 2000 involving EWAN, the Wildflower Society, the local Quairading community, DCLM and the local shire. The aim was to foster interest in bushland restoration and weed management issues.

Participants in a workshop held in the reserve, August 2000.

The work carried out in these bushlands over the last four years forms the basis for much of the information and for most of the case studies. The descriptions highlight how diverse and complex the bushlands around Perth and south west Western Australia can be. Managing them for nature conservation means getting to know individual sites. There are, however, some universal principles and a general approach that can underpin effective management of environmental weeds where they are invading these areas. The following chapter discusses some of those principles and provides an outline of the kind of approach that can be taken when starting out on a bushland restoration/weed management project. Importantly, the kind of area-specific information that is vital to knowing and understanding individual bushlands is also listed.

Chapter 2 Managing Weeds in Bushland

Some General Principles

Weed management in bushland is concerned with much more than simply the elimination of weeds. The underlying objective is always the protection and restoration of diverse natural ecosystems.

South west Western Australia supports one of the most diverse floras in the world, occurring in intricate patterns across a variety of landscapes and soils. For the southern Swan Coastal Plain alone, 1700 native taxa (species, subspecies and varieties) have been recorded occurring in at least 30 different plant communities (Gibson *et al.* 1994, Keighery 1999b). Along a 30 m long and 1 m wide transect through a population of Harlequin Flower (*Sparaxis bulbifera*) invading herblands in the Brixton St Wetlands, up to 28 native taxa and 8 introduced taxa may be found. Bushland weed management in the region is often about working in complex natural systems with a long history of varying disturbances. There is a need to recognise that effective weed management among such diversity begins with knowing and understanding each site; the distribution of the native plants and the native plant communities, the patterns of disturbance and the distribution of weeds. In particular it is important to recognise the locally serious weeds. Only then can weed control and management be strategic – carefully targeted, and tailored to site conditions and available resources.

Gathering area-specific information

Note: *The information listed below is often compiled when bushland areas are being identified for retention or as part of a management plan. When such information is not available it should be compiled as part of the management program.*

Vegetation maps

Vegetation maps of particular bushland areas provide information on the structure and patterns of native flora across different landscapes and soils (see vegetation map of Quairading Nature Reserve, Box 3.2). When carrying out bushland restoration, vegetation maps, accompanied by a flora list, provide a vital reference and an important guide to where in the landscape particular native species occur and the soils on which they generally grow.

Flora list

A flora list aims to record all taxa known to occur at a particular site. A comprehensive flora list is a vital reference for ensuring species not known to occur naturally at a particular site are never introduced as a part of bushland restoration – either through planting or direct seeding.

In addition, flora lists will often indicate the plant communities and associated soils and landforms where particular species can be found growing. At Brixton Street Wetlands for example, such a flora list provided a guide for appropriate selection of species for direct seeding trials located along a degraded edge of herb-rich shrublands on damp, heavy clay soils (see direct seeding case study 5.1). Flora lists should also include weeds – it is important to know all flora and to be able to recognise new weeds as soon as they arrive at a site. Lists will change over time. When our work began at Shenton Bushland 40 species of weeds were recorded. After three years of working and getting to know the site, 25 additional weed species had been identified.

Vegetation condition maps

Impacts of disturbances across a bushland can be recorded in vegetation condition maps. Fire intensity and frequency, weed invasion, soil disturbance, disease, rubbish dumping and past vegetation clearances interact to impact on the species composition, cover and structure of native vegetation. Vegetation condition maps aim to reflect the degree of those impacts. Combined with maps of the distribution of individual weed species, they are useful tools for carefully targeting weed control work to protect relatively undisturbed bushland (Box 2.1). Mapping of vegetation condition requires knowledge of native flora as well as familiarity and understanding of the nature of a particular undisturbed plant community (see Box 7.1 for details on criteria used to map vegetation condition).

Weed maps

Maps that provide a clear understanding of where the serious weeds occur across a bushland site are basic planning tools. They allow for careful targeting of limited resources and provide the information required for strategic weed management. They can provide useful information on the spread of weed populations over time and also provide basic information on the effectiveness of control programs. Not all the weeds in the bushland need to be mapped – only those that have a serious impact. See Chapter 7 for how to create and use weed maps and for some of the criteria that can be used to determine the serious weeds at a particular site.

Fauna information

Information on the area's fauna is also useful. Sometimes weeds can provide habitat or an opportunistic food source for native animals. A list of the known fauna in a bushland can help determine this at a particular site. Gradual removal of such weeds over time may be required while animals find alternative habitat or food sources. For example, dense stands of *Watsonia* can provide important habitat for Bandicoots in the Perth area.

Regional information

Australia is divided up into a series of natural regions. The Swan Coastal Plain and the Wheatbelt are two such regions within Western Australia from where case studies in the text have been drawn. An understanding of a bushland's natural values in relation to others in the region provides information on the area's significance. For example, a bushland may be representative of the more common or rare plant communities in the region. It is important to note that the rarest communities (Threatened Ecological Communities) and flora (Declared Rare Flora – DRF), are protected by laws, either at the state (DRF) or the federal (communities) level. Bush Forever, Volume 2 – Directory of Bush Forever Sites (Government of Western Australia 2000) catalogues information on regionally significant bushland on the Swan Coastal Plain. It provides details on the area of the bushland type that remains uncleared in the region, how much is in conservation reserves, the quality and condition of those bushlands, and where similar bushland can be found. This type of information is important in providing a focus for weed management work, and in gaining an understanding of bushland values that require protection (Keighery *et al.* 1998).

Note: *Bushland restoration carried out where rare flora occurs requires a permit from the Department of Conservation and Land Management* (DCLM).

Developing a weed management program

Resources for bushland restoration work are generally limited. It is critical that these resources are carefully targeted through strategies that prioritise management actions, based on a knowledge of the bushland area and the weeds that are impacting on it. Central to these strategies are a series of principles that are fundamental to successful weed management. Many of the case studies throughout this manual demonstrate the application of these principles:

- Contain the spread of serious weeds and protect intact bushland. Consider the impacts of serious weeds on rare flora and rare plant communities.
- Prevent new weed species establishing.
- Consider restoration of degraded edges. Usually this is of lower priority than protection of good areas. Often though, degraded edges harbour serious weeds, providing a source of propagules that continually disperse into intact areas.

Implementation – taking an integrated approach

Prevent new weeds from establishing

- Clean tools, boots, equipment and machinery between jobs to reduce risk of spread between sites.
- Practise soil hygiene.
- Check paving materials before bringing on to a site, particularly limestone, for weed seed and only acquire from accredited clean sources. Black Flag (*Ferraria crispa*), Geraldton Carnation Weed (*Euphorbia terracina*) and Pretty Betsy (*Centranthus rubra*) to name a few have been introduced to various bushland sites around Perth in paving materials.
- Avoid bringing soil or mulch from elsewhere into bushland.
- Know the plants of your bushland (native and introduced) and immediately remove infestations of any new weeds. This is important at individual sites but also at a regional and state level.

See case study 5.2 on Holly-leafed Senecio (*Senecio glastifolius*) a recent invader to south west Western Australia.

Limit the spread of established weeds

- Target small populations in good bush and the outliers of dense infestations - use the maps (Box 2.1).
- Keep soil disturbance to a minimum. Disturbance favours the establishment of many weeds. It brings buried weed seed to the surface thereby releasing dormancy, and creates favourable conditions for the germination of wind dispersed weed seed.
- Avoid working in areas where weeds are actively shedding seed.
- Post-fire conditions (space, light and high nutrient availability) often favour establishment of weeds. Weed control in the season immediately following fire will prevent seed set in established weeds and reduce germinating weed seedlings. It will limit the inevitable spread of many serious bushland weeds through the post-fire landscape.

See Box 4.2 on fire and cormous and bulbous weeds, Box 5.1 on the weeds that move in with soil disturbance, and Box 3.5 on limiting the spread of Perennial Veldgrass following fire.

Box 2.1 Strategy for the management of Yellow Soldier *(Lachenalia reflexa)* invading a Banksia woodland at Shenton Bushland.

This strategy is simply an illustration of how some of the information covered in this chapter can be used to help set priorities and develop an effective works program.

Biology

Yellow Soldier flowers in winter and early spring, dying back to a bulb over summer. It sets prolific amounts of viable seed (around 40 seed per flower) and up to 1700 bulbs can occur in four square metres. Seed appears to remain viable in the soil for only a couple of years and may be dispersed by water. Plants are not killed by summer fire, but flower well and are highly visible in the post-fire landscape. In addition high numbers of seedlings have been observed establishing on bare ground left following fire.

Suggested Control Methods

For isolated plants in sandy soils use a knife to cut the roots and pull out with bulb in July to early August. Trials have shown metsulfuron methyl at 2.5-5 g/ha, applied just before flowering, in late July, provides effective control with little impact on co-occurring native species. Carefully spot spray.

Recommended strategy for the effective management of Yellow Soldier and regeneration of the Banksia woodland it is invading

Hand-removal of entire populations is time consuming (up to six hours for four square metres) and soil disturbance results in germination of annual weeds. Specifically targeted herbicide treatment is recommended for dense infestations and hand-weeding for isolated plants.

The populations on the eastern side of the reserve and at the southern end of the reserve are both relatively small, occurring in very good to excellent condition bushland and should both be high priority for eradication.

The larger population of Yellow Soldier on the western side of the bushland is spreading through a more degraded area and is not as high a priority if resources are limited.

Following fire, resources should be allocated for control. At this time plants are an easy target for herbicide control and prevention of flowering and seed set will limit establishment in the post-fire landscape.

Allow indigenous species to recolonise the treated sites unassisted (Yellow Soldier co-occurs with up to 25 native species in a 2 m x 2 m plot).

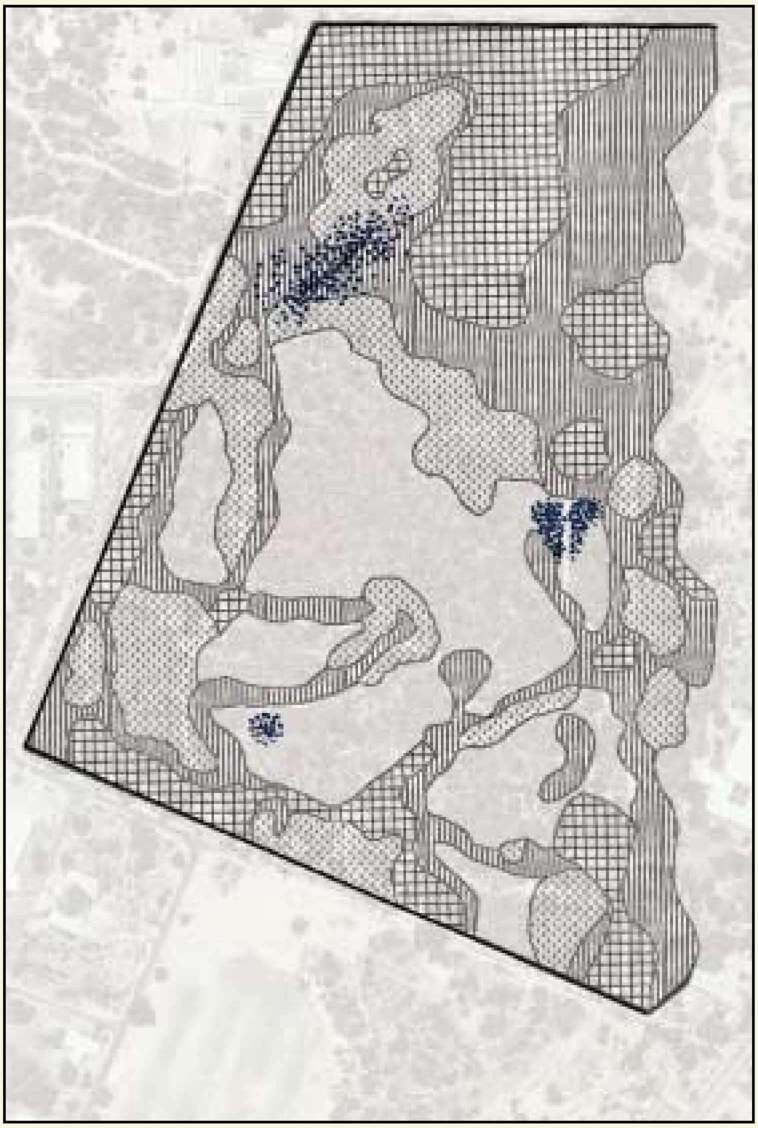


Figure 1. The distribution of Yellow Soldier • and vegetation condition across Shenton Bushland.

Bushland condition

very good - excellent | fair - good | poor | very poor

Understand the biology of a particular weed species – focus on how the weed reproduces and spreads

- When is it actively growing?
- When is it flowering and seeding?
- How long do seed or other propagules remain viable in the soil?
- How does it respond to fire?
- What are the vulnerable times in the life-cycle?
- Is there a preferred time for physical control?
- What is the preferred time for chemical control?

See case study 3.2 on learning about the biology of Tribolium, case study 3.4 on timing Perennial Veldgrass control, Box 4.4 on corm exhaustion and herbicide application and case study 6.2 on timing Fig removal.

Consider all the control options

- Consider the impact of control options on co-occurring native flora including trees, shrubs, geophytes, grasses, and other native herbs and on fauna.
- Physical, chemical and biological methods are all useful in managing bushland weeds.
- A combination of techniques is required for practical and effective long-term outcomes.
- It is important to adapt control methods to site-specific conditions and available resources.

See case studies 4.4 on methods used to control Harlequin Flower (*Sparaxis bulbifera*) and 4.3 on control of Taro (*Colocasia esculenta*).

Assist natural regeneration

- Assist natural regeneration through carefully targeted weed removal.
- Stimulate germination of the native soil seedbank with smoke products or, where the native seedbank is depleted, consider direct seeding. Always use locally collected seed.
- Management practice that favours the regeneration of native plants increases competition against weeds.

See case study 5.1 on direct seeding and Box 5.3 on assisting natural regeneration.

Keep a record of works programs over time

Keeping a record of works programs over time is an important component of bushland restoration. A logbook should record date, time and type of works carried out including details of methods used, hours worked, and site conditions.

Monitor the outcomes of weed management work

Detailed monitoring of weed populations provides a quantitative record of the effectiveness of management programs, measures the impact of the control programs on native plants and the regeneration of the native plant community over time. The feedback provided can be used to adapt future management practices and to justify spending on weed management works.

How you monitor will depend on the changes to be detected, the scale and distribution of the infestation, and the nature of the vegetation the weed/s are invading. Setting up monitoring that is useful for detecting detailed change over time is necessarily complex. For a particularly useful reference see 'Monitoring Plant and Animal Populations' by Elzinga *et al.* (2001). 'The Standard Operating Procedure for Monitoring Weed Control' by the Department of Conservation, New Zealand (2000) is also a particularly useful reference and is designed to provide a detailed working framework for field officers.

Case studies in the tuberous, bulbous and cormous weeds chapter and the grass weeds chapter illustrate some of the methods used over the life of our project to measure the effectiveness of weed management work, impacts on associated native plants and in some cases, regeneration of the native plant community.

See case studies 3.4 in the grass chapter and 4.1, 4.2, and 4.3 in the bulbs chapter.

The following chapters illustrate how the information outlined here underpins effective weed management in bushland and is vital in providing a framework for the protection of unique bushland values. The management of grass weeds is covered first, in the next chapter.

Chapter 3 Grass Weeds

The grass weeds as a group, particularly the South African perennial species, are a serious threat to bushland around Perth. This chapter looks at grass biology and the factors contributing to the invasion and establishment of weed grasses, in particular fire and canopy degradation. The influence of lifeform and growth form on management decisions is highlighted and the importance of growth stage on timing of control programs discussed. Finally, a table with information on the biology of individual species and available control measures is presented.

In terms of number of individuals, biomass, area covered and diversity of habitat, grasses are one of the most successful plant families in the world (Gibbs Russell *et al.* 1991, D'Antonio *et al.* 2000). The characteristics that have contributed to this success have also enabled many grasses to become aggressive invaders of natural ecosystems.

Almost one third of the 709 grass species recorded in Western Australia are exotic (Western Australian Herbarium 1998). In south west Western Australia, 331perennial grasses were introduced and screened as potential pasture species between 1943 and 1970 (Rogers *et al.* 1979). Of these, 14 % are now naturalised in Western Australia (Western Australian Herbarium 1998) and many are now considered weeds of bushland of the Swan Coastal Plain and Jarrah Forest (Keighery 1999a). These include serious invasive grasses such as African Lovegrass (*Eragrostis curvula*), Perennial Veldgrass (*Ehrharta calycina*), Tambookie Grass (*Hyparrhenia hirta*), Kikuyu (*Pennisetum clandestinum*), Fountain Grass (*Pennisetum setaceum*) and the coastal invaders, Marram Grass (*Ammophila arenaria*) and Pyp Grass (*Ehrharta villosa*). Horticulture has also been responsible for the introduction of a number of serious grass weeds, among them Pampas Grass (*Cortaderia selloana*) which is still seen in Perth gardens. However, it is important to identify unknown grass species and not just assume that because it is a grass it is a weed (Box 3.1).

Impacts

Introduced grasses are competitive in many native ecosystems; they may displace the native understorey and alter fire regimes (Humphries *et al.* 1991). The impact a particular grass species has is partly determined by the characteristics of the invaded site (Box 3.2). In south western Australia the annual grasses, Wild Oat (*Avena barbata*) and Blowfly Grass (*Briza maxima*), threaten the herbaceous flora found on the granitic soils of Wheatbelt reserves. Perennial Veldgrass is highly invasive in the sandy, nutrient-poor soils of the Swan Coastal Plain - soils commonly occupied by Banksia woodland. Kikuyu, Water Couch (*Paspalum distichum*) and Vasey Grass (*Paspalum urvillei*) invade the more nutrient-rich wetlands and Tambookie Grass tends to occur on the heavier soils of the Darling Scarp. Grasses often colonise disturbed edges or patches within bushland. This edge colonisation allows the grass to take advantage of any disturbance event within the bushland, establishing rapidly after fire, clearing or soil disturbances.

Box 3.1 Native grasses of the Perth Region

Of the numerous native grasses occurring in Perth's bushland, many are mistaken for weeds. Knotted Poa (*Poa drummondiana*) is superficially similar to Winter Grass (*Poa annua*), while Kangaroo Grass (*Themeda triandra*) is often mistaken for Tambookie Grass. Some native grasses simply look 'weedy' to the untrained eye, including Swamp Wallaby Grass (*Amphibromus nervosus*), Clustered Lovegrass (*Eragrostis elongata*) and Marine Couch (*Sporobolus virginicus*).

Native grasses that occur in the Perth region include:

**Bold indicates that weedy species from the same genus that can be found in the Perth area.*

***Agropyron** scabrum*
***Agrostis** avenacea*
***Agrostis** plebeia*
***Agrostis** preissii*
Amphibromus nervosus
Amphibromus vickeryae
Amphipogon avenaceus
Amphipogon amphipogonoides
Amphipogon debilis
Amphipogon laguroides
Amphipogon strictus var. hirsutus
Amphipogon strictus var. setifera
Amphipogon turbinatus
Aristida contorta
Aristida ramosa
Austrodanthonia acerosa
Austrodanthonia caespitosa
Austrodanthonia occidentalis
Austrodanthonia pilosa
Austrodanthonia racemosa
Austrodanthonia setacea
Austrostipa campylachne
Austrostipa compressa
Austrostipa elatior
Austrostipa elegantissima
Austrostipa flavescens
Austrostipa macalpinei
Austrostipa pycnostachya
Austrostipa semibarbata
Austrostipa tenuifolia
Austrostipa variabilis
***Bromus** arenarius*
Deyeuxia quadriseta
Dichelachne crinita
***Eragrostis** elongata*
***Glyceria** australis*
Hemarthria uncinata
Microlaena stipoides
Neurachne alopecuroidea
Neurachne minor
***Poa** drummondiana*
***Poa** poiformis*
***Poa** porphyroclados*
***Polypogon** tenellus*
***Spinifex** hirsutus*
***Spinifex** longifolius*
***Sporobolus** virginicus*
Tetrarrhena laevis
Themeda triandra

List from Keighery (1999b)

Many grasses use the disturbance caused by bushfire to get a foothold within bushland areas. In turn, grass invasions increase fuel loads which indirectly impact on the native ecosystem by changing fire frequency, intensity, patchiness, size and timing (Humphries *et al.* 1991, Mack and D'Antonio 1998). The introduction of Buffel Grass (*Cenchrus ciliaris*) as a pasture species throughout arid and semi-arid regions of Australia is said to have drastically altered the fire regime. In areas where the grass occurs, fuel loads are high and continuous. Dry water courses which previously acted as fire breaks are now bridged by fire and also act as wicks, spreading the fire further (Humphries *et al.* 1991). More locally, Perennial Veldgrass, Lovegrass and Fountain Grass are all fire adapted, resprouting vigorously and seeding prolifically after bushfires (Christensen and Abbott 1989, Walsh 1994, Milberg and Lamont 1995, Benton 1997, Muyt 2001). Changes in the fire regime can have long term impacts on the structure and composition of the native communities (Williams and Baruch 2000). Indeed, the change in fire regime brought about by Buffel Grass invasion has converted areas of the Sonoran Desert cactus forests of Central America into grassland (Van Devender *et al.* 1997).

Box 3.2 Ecosystem susceptibility: Resource availability, soil structure and Wild Oat

In the Wheatbelt of Western Australia Wild Oat (*Avena barbata*) is often associated with York Gum (*Eucalyptus loxophleba*) – Jam (*Acacia acuminata*) woodlands. The soils of these woodlands are characterised by high values of nitrogen, phosphorus and potassium. They are friable and lack a hard crust, making them more susceptible to weed invasion (Hobbs and Atkins 1988, Arnold *et al.* 1998). The distribution of Wild Oat and Blowfly Grass (*Briza maxima*) at Quairading Nature Reserve illustrates the association between the woodlands and the two annual grass weeds (Figure 1).

The almost exclusive absence of Wild Oat and Blowfly Grass from other plant communities in the reserve may be attributed to a range of factors, poor nutrient levels among them.

Heath and Tamar (*Allocasuarina* species) communities form dense thickets, competing strongly for resources and preventing the majority of light from penetrating the low canopy.

Salmon Gum (*Eucalyptus salmonophloia*) woodlands have an open understorey with large areas of bare ground and only dappled shade. However, even on the reserve edges, there is very little weed incursion. The soils associated with these woodlands form a hard crust, relatively impervious to seeds not adapted to self-burial. Salmon Gums also have an extensive lateral root system near the soil surface competing strongly for available surface moisture and inhibiting establishment of grass weed species (Yates *et al.* 2000).

Wandoo (*Eucalyptus wandoo*) woodlands are slightly more prone to invasion. Like Salmon Gums, Wandoo woodlands have a relatively open canopy, but the soil crust appears less impervious. Where Wandoo blends into Jam, patchy Wild Oat distribution often occurs.

Where Wild Oat occurs within other plant communities it is associated with reserve edges or disturbance from rabbits or machinery. The only exception to this is two small patches growing under the Christmas Tree (*Nuytsia floribunda*). This parasitic plant may increase nitrogen within the soil by accumulating the element from host plants. The nitrogen is then released into the surrounding soil when flowers and leaves are shed (Hocking 1980).

Understanding the relationship between vegetation communities and weed invasions is important to management. Susceptible areas can be targeted for weed prevention and early control. Vegetation maps can be used as a **rough** guide to possible weed distribution at other sites, enabling the estimation of resources required for control.

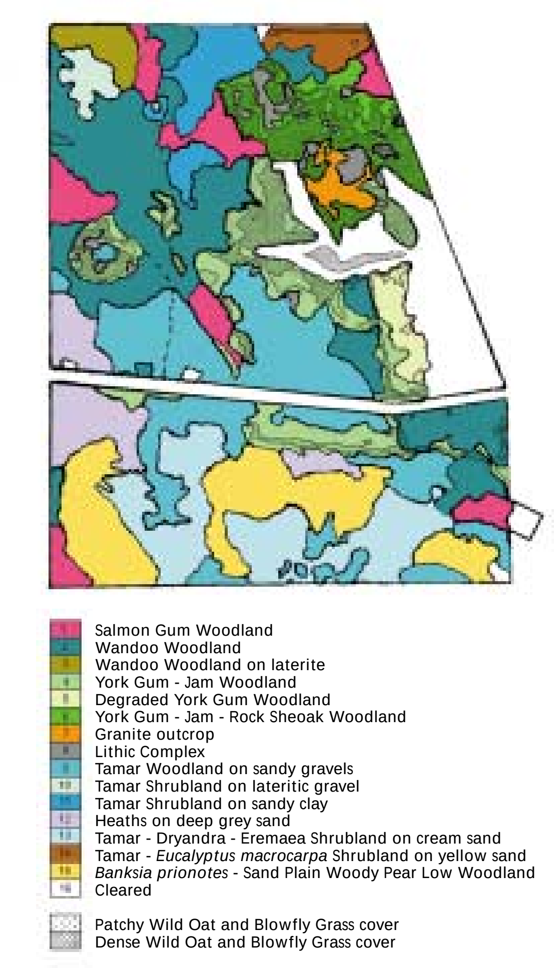


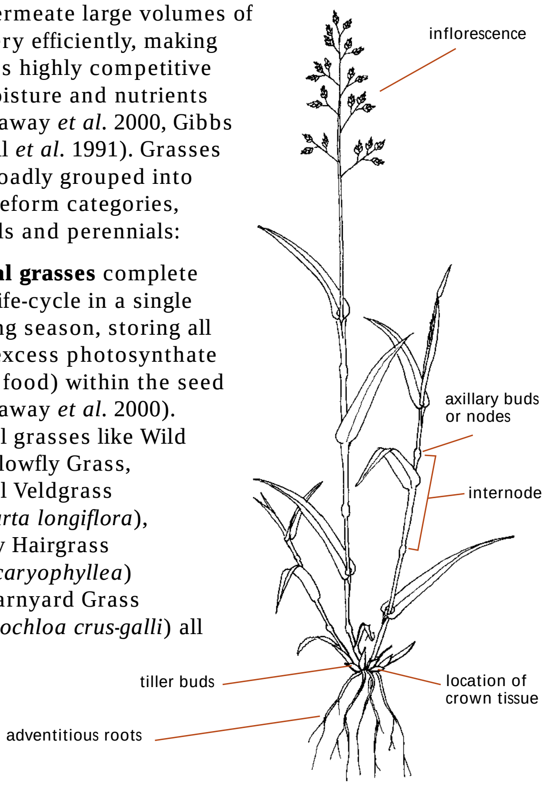
Figure 1. Vegetation complexes occurring within Quairading Nature Reserve, and the distribution and density of Wild Oat and Blowfly Grass across the reserve.

(Vegetation map adapted from Keighery *et al.* 2001)

Fire is less important in the establishment of weedy grasses in wetlands and riparian zones. Instead, invasion of weed grasses is often encouraged by poor land management practices that increase nutrient run-off into streams and wetlands. The disturbance caused by grazing along waterways can also promote the spread of weed grasses. The grasses that commonly invade wetlands are often rhizomatous, their rapid growth and mat-forming habit smothering native plants and preventing further recruitment. Some semi-aquatic grasses, such as Johnson Grass (*Sorghum halepense*), Reed Sweet Grass (*Glyceria maxima*) and Para Grass (*Urochloa mutica*) grow in up to one metre of water. These species can form large floating mats that reduce the habitat of waterfowl, slow and change the direction of water flow, alter silt deposition displace food sources and reduce nesting sites (Humphries *et al.* 1991).

Biology – why are grasses successful weeds?

The structural design of grasses helps make them highly competitive. The presence of axillary buds at the base of each internode allows most grasses to resprout vigorously when damaged (Gibbs Russell *et al.* 1991). This advantage is compounded by the development of crown tissue at the base of the grass plant. Crown tissue produces buds at or below ground level where they are largely protected from the environment. These buds are the source of rhizomes, stolons (Box 3.3) and tillers (new grass shoots or culms arising at or near the base of the primary culm). Soon after a seedling germinates, adventitious roots develop from the crown tissue, firmly anchoring the plant to the ground. These roots store excess carbohydrates and can permeate large volumes of soil very efficiently, making grasses highly competitive for moisture and nutrients (Hannaway *et al.* 2000, Gibbs Russell *et al.* 1991). Grasses are broadly grouped into two lifeform categories, annuals and perennials:



Annual grasses complete their life-cycle in a single growing season, storing all their excess photosynthate (plant food) within the seed (Hannaway *et al.* 2000). Annual grasses like Wild Oat, Blowfly Grass, Annual Veldgrass (*Ehrharta longiflora*), Silvery Hairgrass (*Aira caryophyllea*) and Barnyard Grass (*Echinochloa crus-galli*) all rely entirely on seedling recruitment to establish within an area. Annual grasses are usually tussock forming or caespitose (Box 3.3), although occasionally tillers of prostrate grasses may root at the nodes.

Perennial grasses reproduce vegetatively as well as by seed, storing excess photosynthate within rhizomes, stolons, seed and occasionally corms (swollen underground stem bases). Perennials develop winter- or summer- hardy buds capable of resuming growth the following season (Hannaway *et al.* 2000). Perennials can be sterile and still reproduce vigorously, spreading by stolon, rhizome and dispersal of grass root fragments in water and soil, Kikuyu and Giant Reed (*Arundo donax*) being just two examples. Perennial grasses generally fall into one of three descriptive growth forms, caespitose or tussock-forming, rhizomatous and stoloniferous (Box 3.3).

Reproduction, dispersal and persistence – implications for limiting spread

Sexual reproduction

Seed is important for the spread and establishment of many perennial grasses. For the annual lifeform, seedling recruitment is essential.

Dispersal: An understanding of seed dispersal mechanisms allows us to limit further spread and re-infestation, an important, although often overlooked, component of any management program.

- **Wind** plays a central role in dispersal and many grasses occupy open habitats subject to frequent winds. Small, lightweight seed, suitable for wind dispersal, is the most common form found in the grasses. To further aid wind dispersal the outer bracts may be covered with long soft hairs (Davidse 1986). Seed from adjacent degraded areas can be carried into the bushland by prevailing winds, providing seed rain after a disturbance event such as fire. Depending on the species this deposited seed may establish as a seedbank, ready to germinate given the appropriate conditions.

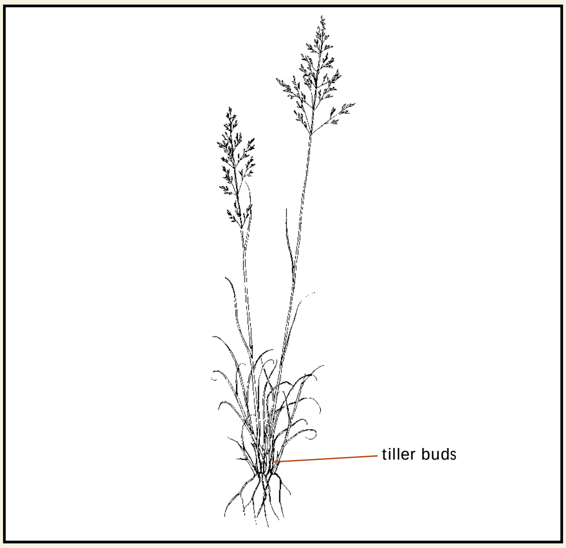
  Once ripe, wind dispersed seed is easily dislodged and careless removal of grass weeds at this stage will facilitate dispersal. Preferably, seed heads should be removed and bagged prior to this stage.

- **Water** can disperse large numbers of seeds. The light weight of many seeds allows them to float easily. Seeds may have aerenchymous tissue, the tiny air pockets aiding flotation. Some seeds have a long awn that helps embed the seed when it reaches a suitable embankment (Davidse 1986). Run-off from rainstorms can carry grass seed downhill and into creeks and storm drains, concentrating vast numbers of seeds in the wetlands they feed into.

  Upstream and uphill source populations need to be managed. Drain outlets can have sumps incorporated to allow weed seed to settle and collect.

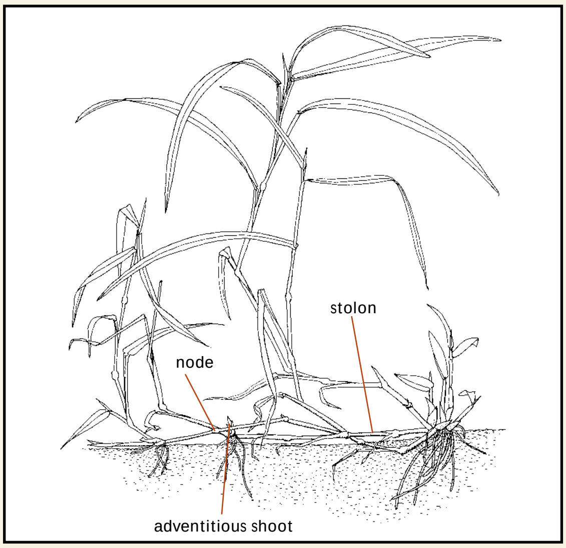
Box 3.3 Grass growth forms

Caespitose or tussock grasses are the dominant grass growth form around the world. Examples include the bushland weeds Perennial Veldgrass (*Ehrharta calycina*), Pampas Grass (*Cortaderia selloana*), Tambookie Grass (*Hyparrhenia hirta*) and Lovegrass (*Eragrostis curvula*). Reproducing by seed and/or tillers they form dense, usually erect, clumps. As clumps age, each year's old leaf material accumulates, creating large fuel loads (Briske and Derner 1998, Hannaway *et al.* 2000). Caespitose grasses typically occupy resource-poor habitats. By accumulating soil organic carbon and nitrogen directly beneath clumps, they monopolise resources (Gibbs Russell *et al.* 1991).



African Lovegrass (Eragrostis curvula)

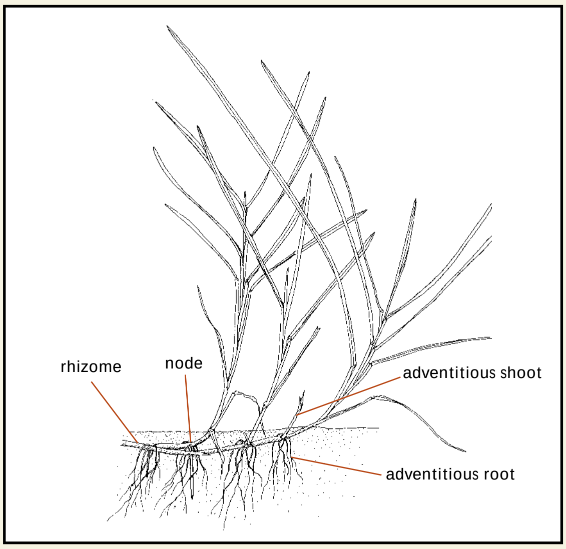
Stoloniferous grasses are creeping or mat-forming grasses that spread locally by stolons and include Para Grass (*Urochloa mutica*) and Queensland Blue Grass (*Digitaria didactyla*). A stolon is a segmented, horizontal stem, which runs predominantly along the soil surface. Adventitious roots and aerial shoots arise from stolon nodes. Stolons themselves arise from adventitious buds in the crown tissue. Propagation is both vegetative, from stolon fragments, and from seed. Although commonly occupying moist, high nutrient areas, some foredune species such as Spinifex (*Spinifex sericeus*) and Saltwater Couch (*Paspalum vaginatum*) are stoloniferous. Many stoloniferous grasses are considered invasive species (Hannaway *et al.* 2000).



Para Grass (Urochloa mutica)

Rhizomatous grasses form dense mats, extending their coverage by producing below-ground lateral rhizomes. A rhizome is a modified underground stem capable of rooting and shooting at nodes to develop daughter plants. They can serve as storage tissue for vegetative propagation and, being underground, are protected from fire. These grasses, including species like Reed Sweet Grass (*Glyceria maxima*), Pyp Grass (*Ehrharta villosa*) and Johnson Grass (*Sorghum halepense*), propagate vegetatively, but may also spread by seed. Rhizomatous grasses dominate moister, more nutrient-rich habitats and are often invasive (Hannaway *et al.* 2000).

Many grasses can be both rhizomatous and stoloniferous, Couch (*Cynodon dactylon*) and Kikuyu (*Pennisetum clandestinum*) being just two examples.



Reed Sweet Grass (Glyceria maxima)

- **Animals** can carry grass seeds on their skin and fur. Seed bracts and/or awns may have sticky hairs, hooks or spines that aid adhesion. Ingestion also plays a role in grass dispersal. Grasses evolved with grazing and several authors have noted seeds are voided intact (Davidse 1986).

  Dogs, horses, native animals and humans (among others) readily disperse seeds along bush tracks. Horses can spread grass weeds from paddocks into bushland, depositing seed with their manure.

- **Human activities** including inappropriate management practices, provide additional mechanisms for grass weed dispersal:

  Grading drags seed (and tillers) along road verges.

  Slashing during flowering spreads seed with an explosive action.

  Lawn clippings dumped in bushland often contain grass seed.

Soil seedbanks: Seedbanks consist of dormant seed, which is ready to germinate given the appropriate environmental cues. Dormancy allows seed to persist in the soil in the absence of further seed rain.

As a general rule grass seeds are not considered to be persistent within the soil. However, there are exceptions. Numerous grasses have a soil seed life greater than five years and not surprisingly many of these are widespread weeds (eg. Fountain Grass and Barnyard Grass). *Poa pratensis* and a number of *Setaria* species are known to remain viable for at least 39 years (Baskin and Baskin 1998). Environmental factors, including temperature, moisture and light intensity can induce dormancy in seeds. For example, deep burial induces dormancy in Wild Oat seed, increasing its longevity from six months to anything up to ten years (Baskin and Baskin 1998, Nugent *et al.* 1999). Dormancy is broken when the seed is returned to the surface through soil disturbance.

For many species, seed longevity is not understood and yet it is invaluable information when making management decisions. The length of a control program is largely determined by seedbank persistence. The shorter lived the seed, the more rapidly a grass infestation can be controlled (provided the source is no longer present or is also managed).

Vegetative reproduction

Vegetative reproduction as a strategy in grasses is most successful in moist, nutrient-rich conditions (Briske and Derner 1998). Under these conditions rhizomatous and stoloniferous grasses can easily establish roots and rapidly disperse rhizome and stolon fragments in soil and down streams. In Reed Sweet Grass (and possibly other species), shoots of young plants can be vegetative or flowering. However, once established, the majority of new shoots produced are vegetative. This strategy allows the plant to quickly colonise new areas by seed, whilst increasing the density of established plants (Department of Primary Industries Water and Environment 2001).

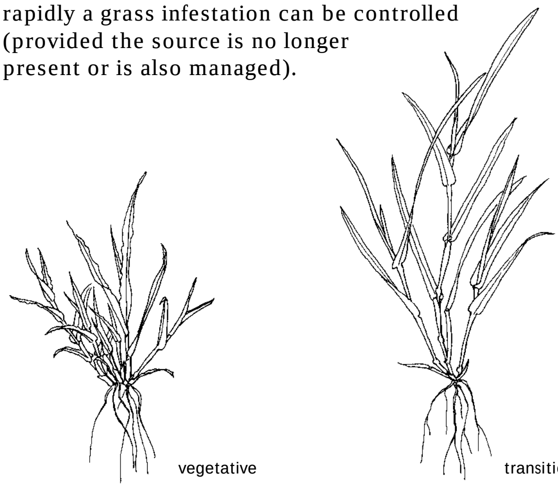
Tussock-forming grasses may also propagate vegetatively. Tillering is responsible for each season's new growth and the expansion in tussock area (Hannaway *et al.* 2000). Tillers are also referred to as sprouts, shoots and daughters and may break off when disturbed.

If resources are scarce, management should focus on controlling the invading edge(s) and new or isolated populations.

Grass growth stages

As with all weeds the timing of grass control measures is important. Active growth is required for herbicide uptake and slashing can enhance leafy growth or result in defoliation, depending on the growth stage. In most grasses (sterile grasses are the exception) there are three main stages of active grass growth: Vegetative, transition and flowering.

- Vegetative growth involves the production of shoots, mostly leaf blades but also stolons and rhizomes. Herbicides are best applied at this stage, while slashing usually results in increased production of leafy material.



vegetative transition

boot stage flowering

- Transition occurs when the growing points stop producing vegetative material and start developing flowers and the tissue between nodes, the internode, elongates. Because of internode elongation, slashing or mowing at this stage can remove many axillary buds, thereby reducing leaf production in the regrowth.
- Flowering begins when the seed head is just emerging from the leaf sheath (boot stage) and continues through to seeding. Some grass-selective herbicides are only effective if applied prior to the boot stage. Slashing or mowing during flowering may facilitate the spread of seed.

The period of **active growth** depends largely on whether the plant is a cool season (C3) or warm season (C4) grass. Cool season and warm season grasses differ in the way they use carbon dioxide. Cool season grasses (Wild Oat, Blowfly Grass, Perennial Veldgrass) photosynthesise more effectively, and thus are most actively growing, during the cooler periods of winter and spring (15-25° C). Warm season grasses, or summer grasses, photosynthesise best with full light saturation and consequently their period of most active growth is late spring and summer (25-40° C). The summer growing Couch *(Cynodon dactylon)*, Kikuyu and Lovegrass are all C4 grasses.

For successful herbicide uptake grasses should be sprayed in the season appropriate to their photosynthetic pathway and when actively growing.

Fire and the spread of grass weeds

Many grasses, especially caespitose species, have long, narrow, vertical leaves that are efficient in strong light allowing sunlight to penetrate deep inside the clump (Gibbs Russell *et al.* 1991). This structure allows the production of a large biomass in a small space. Stems die each year and new ones develop. Over time a large biomass, much of it dead material, creates a significant fire hazard. As a result, grass weed invasions can lead to changes in fire frequency and intensity.

These changes are self-perpetuating as the disturbance caused by fire tends to promote germination and establishment of seedling grasses (Cheplick 1998, Williams and Baruch 2000). At Shenton Bushland, Perth, Perennial Veldgrass was mapped in the year following an intense fire that burnt half of the site. A comparison between a pre-fire bushland condition map and the post-fire Veldgrass map, highlighted a significant post-fire expansion in the population. Previously healthy bushland now recorded 75-100 % cover of Veldgrass (Brown and Marshall unpublished data).

Fire contributes greatly to grass invasion in low-nutrient soils, where post-fire increases in nutrients, light and space availability are more effectively exploited by invasive grasses than by the native flora.

It is important to reduce the possibility of fire in bushland areas at risk of grass invasion. Where bushfire does occur target resprouting plants and seedlings for control before they become established.

Management and control

Prevention and early intervention

Degradation of our native bushland remnants through clearing, fire, disease and mismanagement may be of particular relevance to the establishment and spread of grass weeds. Often an observed decline in the canopy cover within Banksia woodlands around Perth correlates with an increase in the occurrence of Perennial Veldgrass. Reduction in canopy cover leads to an increase in light availability, a condition favoured by many grass weeds (Williams and Baruch 2000, D'Antonio *et al.* 2001).

Weed grass invasion can be limited by:

- Maintaining the bushland canopy. Many grasses prefer open sunny sites and do not establish or compete successfully in the shade.
- Reducing the potential for bushfires. As mentioned, fire can significantly increase the establishment and spread of grass weeds.
- Identifying unfamiliar grasses. It is important to determine if grasses are introduced or native. Early identification of grass weeds allows you to assess the likelihood of invasion and prevents mistaken eradication of native grasses!
- Establishing weed barriers.

Weed barriers

A common grass weed problem in urban remnants is the spread of Kikuyu, Couch or Buffalo Grass (*Stenotaphrum secundatum*) from adjacent parks and road verges. A successful 'weed break' can be created by embedding a physical barrier such as weed mesh or conveyor belt vertically into the ground and using concrete kerbing above it. This prevents rhizomes creeping into the bushland and provides a mowing edge for council mowers (Box 3.4). Some grasses have rhizomes 50 to 60 centimetres below ground and any root barrier must allow for this.

The bush itself often provides an excellent weed break (Box 3.2). However, the sandy soils and open vegetation of Banksia woodland or the friable soils of York Gum–Jam woodlands are more susceptible. Establishing a dense cover of locally-occurring low, medium and tall shrubs along the edges of degraded sites and paddocks could act as a sieve, preventing entry of wind and water carried seed. Knowing the prevailing wind direction, position in the landscape and relationship to waterflow can help to determine if the adjacent paddock, weedy rail reserve or over-run, semi-rural backyard, is the weed source. When planting or direct seeding, use native seed collected from the area of bushland you are protecting and only plant where run-off or prevailing winds are definitely carrying weed seed in.

Box 3.4 Spread of turf grass at Blue Gum Lake

At Blue Gum Lake in the City of Melville, parkland often adjoins bushland. In most of these sites Couch (*Cynodon dactylon*) and Kikuyu (*Pennisetum clandestinum*) have been planted as turf. On one boundary between turf and bushland a large infestation of the woody weed Geraldton Wax (*Chamelaucium uncinatum*) was removed. The site revegetation project was undertaken by the Friends of Blue Gum Lake who were continually faced with Couch that kept creeping back from the grassed area. After spraying the Couch several times an alternative solution was sought.

Creating a physical barrier by using kerbing, was an attractive option. Kerbing was multipurpose: It provided a neat and tidy mowing edge which pleased the local residents and council, prevented the incursion of mowers into the bushland and also limited the spread of Couch. Several stories were circulating regarding the use of rubber conveyor belts buried into the ground vertically and used as barriers to stop rhizome and stolon spread. When a pre-used conveyor belt was donated by Wesfarmers, and the Lotteries Commission agreed to provide funding for the above-ground kerbing, the project was underway.

An outline was created using a rope and marked with stakes. Making an early start, the City of Melville Bushland Works Crew, an enthusiastic Work for the Dole crew and EWAN project officers dug the trench, lay and buried the one metre wide conveyor belt. On several occasions there was grateful acknowledgment that the digging was in sand. In all, it took twelve people four hours. The only hiccups were several large *Banksia* roots, which were dug around, and the conveyor belt cut to fit. A contractor was brought in to do the kerbing, providing the finishing touch. With the donation of the conveyor belt, the labour or in-kind support, the project cost $1164 for 100 metres of barrier – this was all in the kerbing contractor's fees.

While the amenity grass already in the revegetation area still needs to be controlled, once it is eradicated it should be an easier job to keep new incursions out!

Control techniques

Annuals – prevent seed set and limit seedling establishment

Highly disturbed areas are often dominated by annual grasses. Continual removal by physical or chemical means maintains the status quo. In degraded areas the control of annual grasses over the longer term requires the establishment of desirable vegetation (Refer to case study 5.1). However, undisturbed native plant communities are also susceptible to annual grass invasion, such as the understorey of York Gum –Jam woodlands.

To control annual grasses it is essential to exhaust the soil seedbank and limit further seed recruitment. The most effective way of doing this is to prevent seed set or destroy seed before it is shed. The length of the control program will depend on the seed longevity within the soil. The following approaches can be successful if thoughtfully adopted:

- **Hand-weed** small infestations occurring in good condition bushland. Remove weeds prior to seed set. Be aware that seeds can be spread during the weeding process and as contaminants of clothing and tools.
- **Slash** prior to seed set. Timing is important; slash plants after the flower head has emerged but before seed is dry and ready for release. If slashed too early, plants will flower again. Flower heads must be bagged and removed as seed can continue to develop after removal from the plant. Slashing can be labour-intensive in bushland as it must be carefully done by hand to avoid damaging native plants.
- **Spray** germinating weed grasses at the three to five leaf stage with the recommended rate of a grass selective herbicide. This approach may be difficult to apply to species that have staggered germination. Spray such species four to six weeks after rains begin to ensure maximum germination has occurred. Higher rates may be required and an even coverage harder to obtain.

  Research indicates Fusilade® does not impact seriously on established perennial native grasses, although flowering is often inhibited. However, many native grass seedlings appear to be susceptible (Hobbs and Atkins 1988, Hitchmough *et al.* 1994, Davies 1997, Arnold *et al.* 1998, Brown and Brooks unpublished data).

Note: *For many years Fusilade® has been the only grass selective herbicide registered for use in bushland in Western Australia and some annual grass species* (Poa annua, Vulpia spp) *are resistant to the 'fops' group of herbicides to which it belongs. With these problematic species alternatives should be sought* (see weed management table).

A number of other grass-selective herbicides are now the subject of a minor use off-label permit in non-crop situations in Western Australia (until September 2006). Application must comply with all conditions of the permit.
Available from: (http://permits.nra.gov.au/PER4984.PDF).

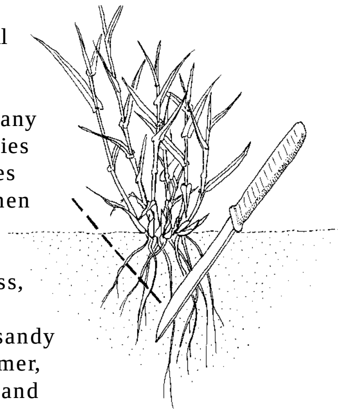
Anyone applying herbicides should have appropriate training in the safe use and handling of relevant chemicals (Chapter 8).

- **Prevent seedling establishment** in highly degraded areas by encouraging the growth of native species and establishing a dense canopy cover. Most grasses prefer open sunny sites for germination.

Perennial grass control

Caespitose grasses

- **Hand-weed** small populations in good condition bushland by using a knife to cut through the roots below the crown tissue. Minimise soil disturbance as much as possible. Care must be taken to remove all dormant buds at the base. These can break off and quickly form new plants. Many apparently caespitose species also produce short rhizomes which must be removed when hand-weeding, eg. Tribolium (*Tribolium uniolae*), Perennial Veldgrass, Vasey Grass. For Perennial Veldgrass, which grows in sandy soils, hand-removal in summer, when the grass is dormant and the roots easily cut through, minimises soil disturbance.



- **Spot spraying** with a grass-selective herbicide controls many perennial grasses. These herbicides are highly selective for susceptible grasses and have little impact on most other species (Preston 2000). In Banksia woodland on the Swan Coastal Plain, Fusilade® (applied at 10 mL/L or 4 L/ha) has been found to have little impact on a wide range of native species (Brown unpubl., Dixon unpubl.)

  With established perennial grasses, grass-selective herbicides must be applied when the plant is actively growing but before boot stage (Parsons 1995). Water stress and nutrient deficiencies can also be limiting factors to growth and must be taken into account. In some grasses the periods of vegetative growth and flowering are short and overlapping. In this scenario there may be little green leafy material prior to boot stage and alternative herbicides or different approaches will need to be tested. One option is the non-selective herbicide glyphosate, which if applied when the developing seed is still like milky dough, will stop seed development and kill the grass. Because glyphosate is non-selective the grass weed must be carefully targeted to avoid damage to surrounding natives. When spot spraying with any herbicide, grass clumps should be sprayed until wet, but without herbicide running off the leaves.

  The dead material retained on the caespitose grass provides protection to other leaves and may result in reduced herbicide uptake. Removing the dead material first (by slashing or taking advantage of unplanned fires) alleviates this problem. The lush regrowth that follows both these events is highly susceptible to herbicide.

- **Slashing** is generally used in conjunction with a herbicide treatment. Tussocks are slashed to the base to remove the bulk of old material and to promote vigorous growth; this should be done during the vegetative phase to maximise the regrowth of leafy green material. When regrowth is lush and vigorous, plants are spot sprayed with the appropriate herbicide. This method has been used successfully by the City of Canning on Pampas Grass invading Yagan Wetlands and is effective in dealing with many large, tussock-forming species. Do not slash when grasses are seeding, as this will assist the spread of propagules locally.

  Continuous slashing of caespitose grasses during the transition phase (when shoot apices are at a vulnerable height) may exhaust their carbohydrate supply, eventually killing the plant. Although herbicide-free and causing minimal soil disturbance this method requires accurate timing, consistent effort and in good bushland each plant must be slashed individually. Resources are rarely available for such intensive control.

  Note: *Slashing without follow-up herbicide treatment may increase productivity of some grasses. This has been recorded for Buffel Grass in the United States (The Nature Conservancy, 2002) and appears to be true of African Lovegrass in the Perth region.*

- **Unplanned fires** require an intensive follow-up program. Resources should be allocated for controlling seedlings and resprouts before the grass problem increases (Box 3.5). Very hot fires can destroy seed close to the soil surface (Smith *et al.* 1999). This reduction in the soil seedbank must be maintained by preventing further seed set from resprouting plants and germinants. Vigorously resprouting plants provide an easy target in the blackened landscape and are readily treated and highly susceptible to herbicides.

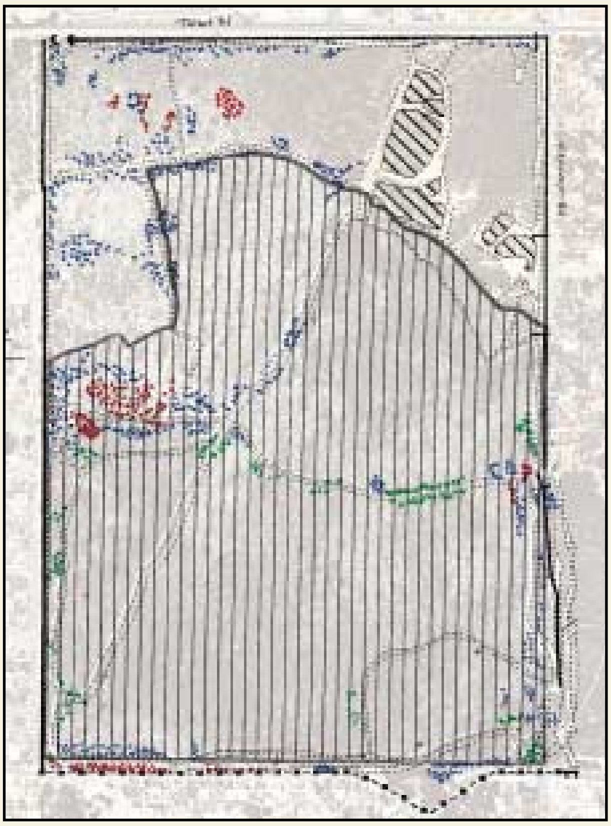
Box 3.5 Making the most of unplanned bushfires

Talbot Road Bushland consists of 60 hectares of Banksia woodland, Marri, Jarrah and Wandoo woodlands and heath. Most is in good condition, but several infestations of weeds capable of moving further into undisturbed bushland are present. Perennial Veldgrass (*Ehrharta calycina*) was one such weed recognised as a problem in the sandier soils. In 1999 the Veldgrass was mapped and light infestations along tracks were hand-weeded to prevent spread into bushland. The presence of the cormous and bulbous weeds, Hesperantha (*Hesperantha falcata*), Freesia (*Freesia alba* x *leichtlinii*) and Watsonia (*Watsonia bulbillifera*), meant control of the main Perennial Veldgrass population was delayed until these serious weeds could be adequately managed.

The Hesperantha, Freesia and Watsonia control programs had been in place for two years when, in the summer of 2000/2001, a fire burnt through some 70 % of the bushland. Part of the Perennial Veldgrass population was burnt and much of the remaining unburnt area was infested. Amid fears that the grass would quickly establish over a wider area, flourishing under the post-fire conditions, resources were made available for control.

In July, following the fire, a contractor was employed to spray the remaining unburnt Perennial Veldgrass before seed set. Treating the area that had burnt was more complicated. The Perennial Veldgrass distribution map made in 1999 was used to locate where the Perennial Veldgrass was. Resprouting clumps were carefully spot sprayed and seedling flushes blanket sprayed, taking care not to trample resprouting natives. The areas adjacent to the mapped populations and any gullies or wash areas were also carefully searched and seedling flushes treated. To minimise damage to native plants the grass selective herbicide Fusilade® (10 mL/L) was used.

Note: *The susceptibility of Perennial Veldgrass seedlings to lower rates of Fusilade® requires research. If lower rates were known to control the weed, the amount of herbicide introduced into the bushland could have been reduced.*



• 61 - 100% • 6 - 60% • 0 - 5% cover

After the fire in December 2000 (lined area) a 1999 map of Perennial Veldgrass distribution at Talbot Road Bushland was used to determine priority areas for spraying in July 2001.

Rhizomatous and stoloniferous grasses

Hand-weeding should only be considered for very small infestations (less than one meter square) when soil is moist. It is important to remove all root, rhizome and stolon fragments or plants will rapidly regenerate. For some species like Para Grass and Johnson Grass, rhizomes can extend for up to two metres. However, because of the extensive soil disturbance involved, hand-weeding is generally not recommended in bushland.

Herbicide can be blanket sprayed over the dense mats commonly formed by rhizomatous and stoloniferous grasses. A systemic herbicide that is translocated through all parts of the plant, including the rhizomes and stolons, must be used. Where native plants are present, grass-selective herbicides are necessary to avoid off-target damage. Without thorough foliage coverage, the amount of herbicide absorbed into the plant is not sufficient for effective control. Even with good coverage, many rhizomatous grasses require multiple spray treatments within a single season; only a few rhizomes or stolons need to survive for the plant to rapidly re-establish.

Herbicide use near waterways becomes an important issue where many rhizomatous and stoloniferous grasses are invasive. At present Roundup Biactive® is the only herbicide registered for use near water. Many of the wetlands of the Swan Coastal Plain are seasonal and dry up over the summer months. Luckily, summer coincides with the active growth of most wetland grasses and spraying can be done at this time. Grasses that grow in permanent water bodies will need to be either treated with Roundup Biactive® or pulled from the water and methods such as solarisation tried.

Solarisation is useful for controlling summer growing (C4) grasses in highly disturbed areas. This involves laying heavy duty plastic sheeting (black or clear) over part or all of the infested area. With edges firmly held down, the plastic is left in place for four to twelve weeks before being removed. The plastic sheeting traps the heat, increasing the soil temperature to levels that kill plants, seeds, plant pathogens and insects (Bainbridge 1990). The use of clear plastic results in higher soil temperatures, whereas black plastic prevents photosynthesis and this contributes to plant death. The method is most effective when applied during the hot summer months and is only really useful in sites where the soil is moist (Tu *et al.* 2001). The area may need to be blanket sprayed after any surviving grass has regrown vigorously.

Establishing shade along bushland edges by encouraging the regeneration of local plants can inhibit the spread of many amenity grasses from adjacent parklands. Kikuyu, Buffalo Grass, Couch and similar amenity grasses are often intolerant of shade.

Monitoring and follow-up

It is important that grass control is done effectively and that any control program does not simply enhance the competitiveness of other serious weeds. With control programs for grass weeds in small urban bushlands costing up to $1000 per hectare, monitoring their success is essential.

Monitoring provides a quantitative record of the management program, measures the impact of the control program on native plants and ensures value for money from contractors. How you monitor will depend on the changes to be detected, the type and patchiness of vegetation and the terrain. Case study 3.4 provides a detailed example of monitoring a Perennial Veldgrass control program in Banskia woodland.

Regardless of the control method used, follow-up treatment in subsequent years is usually necessary. Plants that were missed or survived the first treatment will need treating and soil seedbanks may take several years to deplete. If follow-up does not take place, the initial effort and resources will be wasted.

Key points

The information presented in this chapter highlights a range of management issues concerning grass weeds and how these relate to the biology of this group. Briefly:

- Invasion of many grasses is often facilitated by fire and loss of canopy cover.
- Annual grasses are generally weeds of highly disturbed areas, although there are exceptions (Wild Oat, Annual Veldgrass). To control, prevent seed set over successive years and establish desirable vegetation.
- Perennial grasses can threaten intact bushland. They are grouped into the tussock-forming caespitose grasses and the mat-forming rhizomatous or stoloniferous grasses. Management strategies and control techniques differ for the different growth forms.
- Recognising and treating grasses at the appropriate growth stage is integral to a successful outcome of any control program.

The case studies described below bring together this information, providing an example of management in action for an annual, a perennial caespitose and a rhizomatous grass. A fourth case study describes the monitoring of a Perennial Veldgrass control program at Blue Gum Lake. Following the case studies is a table of currently available information on the control of grass weeds.

One aspect of their biology that has contributed greatly to the success of the grasses is the ability to store carbohydrate reserves in tillers and rhizomes at the base of the plant. This strategy is taken even further by the group of plants covered in the next chapter. The bulbous, cormous and tuberous species are another group successfully naturalising in south west Western Australia. Their success, in part, is due to an ability to die back to underground storage organs over our long dry summers.

Case study 3.1 Managing the annual grasses Wild Oat *(Avena barbata)* and Blowfly Grass *(Briza maxima)* at Quairading Nature Reserve

An informative case study on the control of the annual grasses Wild Oat (*Avena barbata*) and Blowfly Grass (*Briza maxima*) within bushland comes from a trial at Quairading Nature Reserve. Wild Oat and Blowfly Grass are winter-growing annuals that rely on successful seed set and recruitment into the soil seedbank to persist.

The aim of the trial was to reduce, if not eliminate the Wild Oat seedbank, and give a competitive advantage to the native annual herb and perennial grass species. The possibility that other annual or perennial weeds would fill the niche also required consideration and a monitoring program was put in place to record changes in vegetation cover and species diversity over time.

Setting up the demonstration site

The trial was designed to reduce external seed contamination from surrounding weed grasses. Changes in weed, native grass and herb cover were monitored over three years and the effectiveness of direct seeding evaluated.

The design: Two large, 20 metre square permanent plots, a control and a treatment, each housed five randomly placed one metre square quadrats. A third 20 metre square plot, for testing direct seeding, was established in the second year of the trial. It housed ten one metre square quadrats of which half were used for controls.

Treatment: Fusilade® (500mL/ha) + Pulse® (2 mL/L) was blanket sprayed over the treatment and direct seeding plots in early August when the Wild Oat was at the three to five leaf stage and around 10 cm high (Table 1). A local farmer carried out the spraying.

In August 2000, direct seeding trials were carried out by sowing native seed collected from the site over the 20 m x 20 m quadrat apart from five of the 10 subquadrats (1 m x 1 m) which were covered during the sowing. These were the controls. Seed was from a range of annual herbs and perennial grasses including *Neurachne alopecuroidea*, *Austrostipa elegantissima*, *Austrostipa tenuifolia*, *Waitzia acuminata* and *Rhodanthe manglesii*.

Data collected: Each year, in late spring, weed and native species present in each quadrat were recorded, counted and their percentage cover estimated and assigned to a cover class: **1** (<1%), **2** (1-5%), **3** (6-25%), **4** (26-50%), **5** (51-75%) and **6** (76-100%) (Braun-Blanquet 1965).

Table 1. Years in which plots were sprayed, seeded and scored.

	1999	2000	2001
CONTROL	score	score	score
TREATMENT	spray + score	spray + score	score
DIRECT SEEDING	-	spray score + seed	score

Results

Wild Oat and Blowfly Grass control: In 1999 and 2000, the treatment plot was almost free of grass weeds within six weeks of being sprayed, a distinct patch within a sea of oats (Figure 1).

There was little further germination as the season progressed. In contrast, the control was a mass of Wild Oat and Blowfly Grass.

By 2001 the Wild Oat and Blowfly Grass seedbanks were more or less exhausted. Even though the plot was not sprayed again, Wild Oat and Blowfly Grass cover remained under 10 % compared with the almost 80 % cover observed before the treatment began.

Blowfly Grass probably contributed to the majority of cover in 2001, although this was not measured. Blowfly Grass has a more persistent seedbank (Raynor 1989 in McMahon 1991) than Wild Oat, which has a seedbank half-life of six months under non-tillage conditions (Nugent *et al.* 1999). That is, half the seed remaining in the soil dies every six months.

Other annual grass weeds: Three other annual grass weeds were recorded in the plots, Silvery Hairgrass (*Aira caryophyllea*), Silver Grass (*Vulpia myuros*) and Annual Veldgrass (*Ehrharta longiflora*). Silver grass is known to be resistant to the 'fops' group of herbicides that Fusilade® belongs to (Chambers and Andreini 2000). Therefore, it was possible that this grass would increase in the absence of competition from other annual

Figure 1. In September 1999 the edges of the treatment plot are clearly marked by a border of Wild Oat and Blowfly Grass.

grass weeds. It didn't. Silver Grass cover remained low throughout the three year trial period, as did cover of Silvery Hairgrass.

In contrast, Annual Veldgrass seedlings are susceptible to Fusilade® (Davies 1997, Brown unpublished data) and like Wild Oat, germination is in the few weeks following the opening rains (Davies 1997). Like Wild Oat, two years of treatment appeared to exhaust the soil seedbank of Annual Veldgrass at the site. However, there was an indication that a single treatment could result in Annual Veldgrass becoming a serious weed in the absence of Wild Oat competition.

***Non-grass weeds*:** In total, there were 12 weeds present at the site, including the Wild Oat and Blowfly Grass - none were invasive perennials. Only Flatweed (*Hypochaeris glabra*) and Ursinia (*Ursinia anthemoides*) showed a noticeable response to the removal of Wild Oat and Blowfly Grass. The number of Flatweed plants increased within the treatment plot by over 30 % from 1999 to 2001, but decreased in the control by 80 %. This suggests Flatweed has a stronger competitive advantage than the native annual flora, but is weaker against Wild Oat and Blowfly Grass, especially in poor years when moisture is scarce.

The native flora

As the 1999 season unfolded, colour erupted in the sprayed plot (Figure 2). A mass flowering of native annuals occurred. These species, while found in the unsprayed plot, were largely smothered there by Wild Oat and Blowfly Grass.

***Native annual and perennial herbs*:** There was little indication that the Fusilade® harmed the native annual and geophyte flora. The decrease in competition from Wild Oat and Blowfly Grass appears to have benefited the geophyte life-form over time. Initially geophyte numbers were significantly lower in the treatment plot, but, after two years of treatment, numbers were similar in both plots.

Two native annual herbs apparently affected by the density of Wild Oat and Blowfly Grass were *Waitzia acuminata* and *Phyllangium sulcatum*. Both species decreased in the control plot over the three years and remained similar (*P. sulcatum*) or increased (*W. acuminata*) in the treatment plot.

***Native grasses*:** Mature clumps of eight native grasses (*Aristida contorta, Austrodanthonia caespitosa, Austrodanthonia setacea, Austrostipa elegantissima, Austrostipa tenuifolia, Austrostipa trichophylla, Eriachne ovata, Neurachne alopecuroidea*) suffered only temporarily from the herbicide treatment. Seedling recruitment observed in 2001 suggests that the removal of competition by Wild Oat and Blowfly Grass will allow native grasses to become more dominant over time.

Figure 2. Looking back over the treatment plot in October 1999 - a profusion of wild flowers.

Herbicide treatment appeared to inhibit flowering in the native grasses. *Aristida contorta* and *N. alopecuroidea* in particular flowered profusely outside the treatment plot, while flowers were all but absent on tussocks inside the plot. A reduction in flowering of native grasses after Fusilade® treatment has also been recorded in a study by Hitchmough *et al.* (1994). Although this and other studies (Hitchmough *et al.* 1994, Davies 1997) indicate mature native grasses only suffer temporary adverse effects to Fusilade® treatment, impacts need to be carefully monitored. Fusilade® is highly phytotoxic at the 3-5 leaf stage on most native grasses tested (Hitchmough *et al.* 1994). The continued treatment of an area may inhibit recruitment of native grasses and inevitably lead to a reduction in native grass cover and local diversity.

Direct seeding trials

The aim of the direct seeding trial was to tip the competitive balance in favour of the native flora. Exotic grasses were controlled with the early herbicide treatment and the native seedbank was boosted by direct seeding with locally collected native herb and grass species. The direct seeding trial plot was both species-poor and had low cover and numbers of native plants. Following the direct seeding of native herbs and grasses in August 2000 there was no significant, or indeed obvious, increase in these figures.

The failure of the sown seeds to germinate can be attributed to a number of factors. Although the seeds were viable, the dry winter and lack of soil moisture may have inhibited germination. Large amounts of seed may have blown away. It is important to note that any sort of soil disturbance that may have enhanced germination of broadcast seed would also enhance weed invasion. Time of sowing, seed treatment and lack of surface preparation may all be wholly, or partly responsible. It is possible that the site itself did not favour the germination of annual herbs; there were very few areas of bare soil within the plot. Further research into direct seeding in these woodlands is clearly required.

Conclusion

Overall the demonstration site and trials were a success. Wild Oat, Blowfly Grass and Annual Veldgrass soil seedbanks were depleted by two years of treatment. In the right situation native herbs flourished in the absence of Wild Oats and native grasses did not suffer permanent damage. Other annual weeds failed to become a serious problem and with continued research into direct seeding, the competitiveness of the native plant community could be further enhanced.

Applying this information to the control of other annual grasses

Seedbank persistence is indicative of the required length of the control program.

Using this approach to control grasses with more persistent seedbanks may severely impact on native grasses.

A single spray early in the season will not be so effective on weed grass species with staggered germination.

It is important to know what other opportunistic weed species may take advantage of the space created by removal of annual grass weeds. It is unwise to remove an annual grass if it will lead to establishment of a more serious weed.

In many circumstances the removal of annual grasses may leave bare areas of ground that are open to invasion. In these circumstances direct seeding may be appropriate.

Case study 3.2 Managing the perennial caespitose grass, Tribolium (*Tribolium uniolae*), invading threatened ecological communities in the Brixton Street Wetlands.

Tribolium (*Tribolium uniolae*), a tussock-forming perennial grass, is a native of South Africa where it is found in the winter rainfall areas of the Cape Province. A highly variable species, this grass appears able to exploit new habitats where they arise. Common as a 'roadside weed' it successfully invades disturbed ground and responds positively to scrub fires (Linder and Davidse 1997).

At Brixton Street Wetlands Tribolium is invading Marri woodlands, herb-rich shrublands and to a lesser degree claypans. Large clumps are displacing the very rich annual and perennial herbaceous flora that grows there.

In the past Tribolium has been successfully treated at Brixton Street with the non-selective herbicide Roundup® at 10 mL/L. Recently the weed was recorded spreading into undisturbed bushland so more selective control methods were required.

Herbicide trials and standing water

Some areas of Brixton Street are inundated for part of the year and herbicide application can be inappropriate. Unfortunately, when the wetlands are dry from January through to May, Tribolium is usually dormant. Active growth starts in June following the first rains and by the time the wetlands begin to dry out in late October, flowering is underway.

Grass-selective herbicides should normally be applied before the boot stage (Parsons, 1995). However, the issue of standing water was important so it became necessary to investigate an application at the post-boot stage. The initial herbicide trials took place in November. There was still plenty of leaf material, but plants were flowering. Two different grass-selective herbicides, Fusilade® and Sertin Plus®, both with the addition of Pulse®, were tested on older plants (characterised by much dead material surrounding a few actively growing leaves and stems) and younger plants (mostly leafy green material).

Figure 1. Tribolium growing in the bushland at Brixton Street.

The trials were simple: Five sets of three 2 m x 2 m quadrats were set up within a population of mature plants (five Fusilade®, five Sertin Plus® and five control plots). For the younger plants, which occurred at much higher densities, three sets of three 1 m x 1 m plots were used. Plants were counted prior to treatment and scored again after the emergence of green material the following June.

Older plants Given the small number of actively growing leaves, older plants were perceived as difficult to kill and Fusilade® was applied at a high rate (15 mL/L). Both herbicides tested on mature flowering plants were effective, particularly the Fusilade® treatment in which no plants survived. However, only 48.3 % of plants in the control plots survived the trial period (Table 1). The high levels of natural senescence may be the result of an extremely dry summer or simply reflect the age of the population, factors that may also have contributed to the high death rate in the treatment plots.

Younger plants Herbicide applied during flowering (November 2000) was ineffective on younger plants. Further trials were conducted in August when plants were actively growing yet not quite flowering (ie. before the boot stage). This time herbicide treatment was effective (Table 2). The presence of standing water limits Fusilade ® application to dry areas.

Fire

In January 2000 an unplanned fire burnt through the southern section of Brixton Street destroying earlier herbicide trials. However, pre- and post- fire counts of Tribolium plants in the control plots provided useful data on the weed's response to fire. An average of only 26 % of plants resprouted following the fire, but by June 2000 an abundance of seedlings was observed in the plots and surrounding burnt area.

The fire provided an excellent control opportunity. As well as killing 74 % of plants in the plots, the remaining plants were vigorously producing tillers before the break of season and winter rainfall. This was also well before most of the native vegetation had begun to recover from the fire. In the blackened landscape the green Tribolium plants were highly visible and easy targets for spraying (Figure 2).

In May 2000 the effectiveness of Roundup® and Fusilade® (both 10 mL/L) at controlling plants resprouting from burnt clumps was compared. The number of actively growing plants in three sets of three 2 m x 2 m plots (three controls, three Fusilade®, three Roundup®) were counted before, and then six weeks after treatment. At the time of treatment Tribolium plants in unburnt vegetation were still in the dry dormant stage with no visible green growth.

Both herbicide treatments were effective. A mean of only 2.2 % survived the Roundup® treatment and a mean of 5.4 % the Fusilade® treatment (Table 3). Furthermore, seedlings that were prolific in post-fire vegetation were effectively controlled with Fusilade® at 10 mL/L.

Table 1. Mean percentage of Tribolium plants surviving in trial plots following herbicide treatments on older flowering plants.

TREATMENT	GROWTH STAGE	DATE	MEAN SURVIVAL (%)	SE +/-
Fusilade 15 mL/L + Pulse 2 mL/L	older plants, flowering	Nov 2000	0	
Sertin Plus 12 mL/L + Pulse 2 mL/L			19.5	5.74
Control			48.3	14.7

Table 2. Mean percentage of Tribolium plants surviving in trial plots following herbicide treatments on younger plants at flowering and just prior tp flowering.

TREATMENT	GROWTH STAGE	DATE	MEAN SURVIVAL (%)	SE +/-
Fusilade 10 mL/L + Pulse 2 mL/L	younger plants, flowering	Nov 2000	54.2	11.29
Sertin Plus 12 mL/L + Pulse 2 mL/L			56.3	5.6
Control			88.8	14.7
Fusilade 10 mL/L + Pulse 2 mL/L	younger plants, prior to flowering	Aug 2001	3.9	0.93
Fusilade 10 mL/L + DC-trate 2 mL/L			11.3	4.83
Control			96.4	2.48

Table 3. Mean percentage of Tribolium plants surviving in trial plots following herbicide treatments on plants resprouting after a January fire. Value greater than 100 % indicates recruitment.

TREATMENT	GROWTH STAGE	DATE	MEAN SURVIVAL (%)	SE +/-
Fusilade 10 mL/L + Pulse 2 mL/L	resprout from Jan 2000 fire	May 2000	5.4	2.9
Roundup 10 mL/L + Pulse 2 mL/L			2.2	5.12
Control			100.8	5.1

Figure 2. Tribolium vigorously resprouting after fire.

Hand-weeding

Physical removal of Tribolium by cutting below the base with a sharp knife is one option appropriate for small, isolated populations when the soil is moist. However, this method is labour intensive and impractical on a larger scale. Where the grass grows very closely among native plants it is difficult to remove without damaging native vegetation.

The effectiveness of hand-weeding is somewhat compromised by the ability of Tribolium to reproduce from small, adventitious buds that break off from the base.

Management

Effective management of Tribolium invading bushland relies on control of mature plants as well as subsequent seedling recruits. It is clear that the weed can be effectively controlled with grass-selective herbicides. However, chemical control of established plants is only going to be one part of any strategy.

As well as understanding how to control Tribolium, it is important to understand how the weed is dispersing and spreading. At Brixton Street dispersal is by the seed, which is light in weight and small in size. Sheet water flow occurring across the wetlands in winter probably carries seed into undisturbed bushland. Ants may also be moving seed around, with seedling recruitment consistently observed around their nests (Figure 3).

Keeping fire and other disturbances out of the bushland is essential to stop the spread of Tribolium. Seedlings are able to exploit space, light and nutrients, made available by fire, establishing early and out-competing regenerating native species. Any unplanned fire, however, should be taken as an opportunity to effectively control mature plants and the subsequent seedlings. Without follow-up control of germinants, fire will almost certainly contribute to the further spread of Tribolium in the bushland.

Over the winter of 2001, seedling recruitment was also observed in plots where there had been high levels of senescence among mature plants (both natural and as a result of herbicide treatments). As tufts of perennial grasses die back, gaps are created that are available for colonisation by seedlings (O'Connor and Everson 1998). Using baseline distribution maps of the weed, it will be necessary to systematically monitor the bushland for seedling recruitment over a number of years. Knowing how long seed remains viable in the soil is important in management planning for follow-up work and is an area requiring further research.

The management focus at Brixton Street is protection of the native plant communities, not just eradication of Tribolium. Consequently, plant species moving into the gap created as the weed is removed will need to be carefully monitored. There are other serious perennial weeds invading the wetlands that have the potential to recolonise the treated sites, including Harlequin Flower (*Sparaxis bulbifera*), *Watsonia* species, *Gladiolus undulatus* and African Lovegrass (*Eragrostis curvula*). These are all subject to fairly intensive control programs at present.

Source: Brown and Brooks (In press a)

Figure 3. Tribolium plants growing vigorously around an ant nest.

Case study 3.3 Managing the rhizomatous Reed Sweet Grass *(Glyceria maxima)* at Gingin Brook

Reed Sweet Grass (*Glyceria maxima*) was introduced to Australia as a pasture grass for continuously and seasonally wet areas (Humphries *et al.* 1991). However, in Australia and New Zealand it accumulates toxic levels of hydrocyanic acid, which has resulted in cattle deaths from cyanide poisoning (DPIWE 2001).

A grass of temperate regions, Reed Sweet Grass rapidly became a weed of waterways and wet meadows in southern Australia (Humphries *et al.* 1991, DPIWE 2001). Reaching heights of over two metres, this robust perennial is capable of rapidly forming large infestations. Factors contributing to its success include:

- Prolific seeding throughout summer and autumn especially in newly establishing populations (DPIWE 2001).
- Varying levels of dormancy (immediate germination through to dormancy for several years) (DPIWE 2001).
- Development by seedlings of an extensive mat of roots and rhizomes in the first year of growth (DPIWE 2001).
- Quick expansion from the mat of rhizomes, or underground stems, which comprise 40-55 % of the plant's total biomass (DPIWE 2001).
- Growth in mats on water to one metre deep, out-competing native aquatic plants.
- Spread of seed and rhizome fragments in water, in mud on machinery and vehicles, on footwear and by livestock.

In Tasmania, a common control method for larger infestations is foliar spray using a 1-3 % solution of glyphosate (Roundup Biactive®) during late summer through to early autumn. Translocation of photosynthates, and thus herbicide, may be best at this time; the plant is storing carbohydrates in the rhizomes in preparation for overwintering and growth in the following season (DPIWE 2001). Follow-up treatments early in the following summer are recommended. Plants that have more than about one-third of their stems below water might not be killed by herbicide.

Reed Sweet Grass at Gingin Brook

Reed Sweet Grass is one of several serious weeds invading the last remaining Flooded Gum (*Eucalyptus rudis*) – Swamp Paperbark (*Melaleuca rhaphiophylla*) woodlands fringing the Gingin Brook. With very little natural vegetation remaining along the brook, it was important to implement a management strategy that would remove the grass and allow the native flora to recolonise the area. Because the grass grows closely amongst native vegetation, the use of a non-selective herbicide was inappropriate.

Treatment: To observe the effectiveness of the grass-selective herbicide Fusilade® at controlling Reed Sweet Grass, a single 5 m x 5 m plot was permanently marked. The percentage cover of natives and weeds was recorded and the grass sprayed with Fusilade® 10 mL/L plus Agral® 3.5 mL/L late in February, 2000.

Results: Before treatment, Reed Sweet Grass covered 90 % of the plot while the native Tassel Sedge (*Carex fascicularis*) and Tall Sedge (*Carex appressa*) covered the remaining 10 %. By November 2000, Reed Sweet Grass covered only 25 % of the plot and most of this appeared to be reinvasion from the edges. Tassel Sedge and Tall Sedge now covered 25 % of the plot and a carpet of *Carex* seedlings and the occasional Flooded Gum and Swamp Paperbark seedling were recorded.

Scaling up: Given the encouraging results, it was decided to spray the whole population with 10 mL/L Fusilade® and Pulse®. The trial plot was also resprayed. It was planned

Reed Sweet Grass forms a dense mass across the trial plot and surrounding areas.

Reed Sweet Grass extending stolons into a bare area.

to spray the infestation twice over summer – when the area was dry. Therefore, in contrast to the late-summer spray within the trial plot, the initial treatment was carried out in early summer (November 2000).

By February 2000, cover of Reed Sweet Grass within the trial plot (now sprayed twice) was reduced to 5 %, *Carex* cover remained at 25 % and there were still many *Carex* seedlings. There was also an array of annual weeds and two perennial weeds flourishing in the bare soil. Outside the trial plot was a different story. Although Reed Sweet Grass was damaged by the November treatment, there was still substantial cover across the area. The November treatment was clearly not as effective as the late February treatment had been. This may have resulted from the different treatment time or the use of a different wetting agent. Some *Carex* plants were also damaged. Unfortunately the second herbicide application planned for late summer could not be made due to early rains that inundated the area.

Management implications: This case study illustrates the possible importance of timing and wetting agent used in determining the outcome of a particular treatment. Before scaling up it is important to consider all factors when looking at the results of trials.

Note: *Reed Sweet Grass quickly becomes a large and vigorous plant and new infestations should be treated immediately. If control is delayed, eradication in one season is improbable and follow-up work over at least two or three seasons will be required (DPIWE 2001).*

Case study 3.4 Monitoring the effect of Fusilade® treatment on Perennial Veldgrass (*Ehrharta calycina*) and the native plant community in a Banksia woodland

At Blue Gum Lake, plots were put in to record the effectiveness of a Perennial Veldgrass (*Ehrharta calycina*) control program and to answer the question 'what will return once Perennial Veldgrass is controlled?'.

The four year control program adopted an integrated approach. Contractors sprayed the dense infestations with Fusilade® at 4 L/ha and the Friends of Blue Gum Lake hand-weeded light infestations one day each summer in the areas of good bushland. Maps of the grass distribution and density, created prior to and after the control program, provided a broad measure of effectiveness (Figure 1a and 1b). The Veldgrass density was estimated for 20 metre squares on a grid basis over the bushland.

Permanently marked plots to monitor the changes in vegetation composition, quantify the success of the spray program and assess the spray contractor's efficiency were put in place in August 1998. Five treatment and five control plots (each two metres by two metres) were set up within a densely infested area (Figure 2). Mature and seedling Veldgrass plants were counted. All other species were recorded and the percentage cover of weed species within each plot estimated. When the infestation was sprayed the control plots were left untouched. Each year, all plots were re-scored immediately prior to treatment.

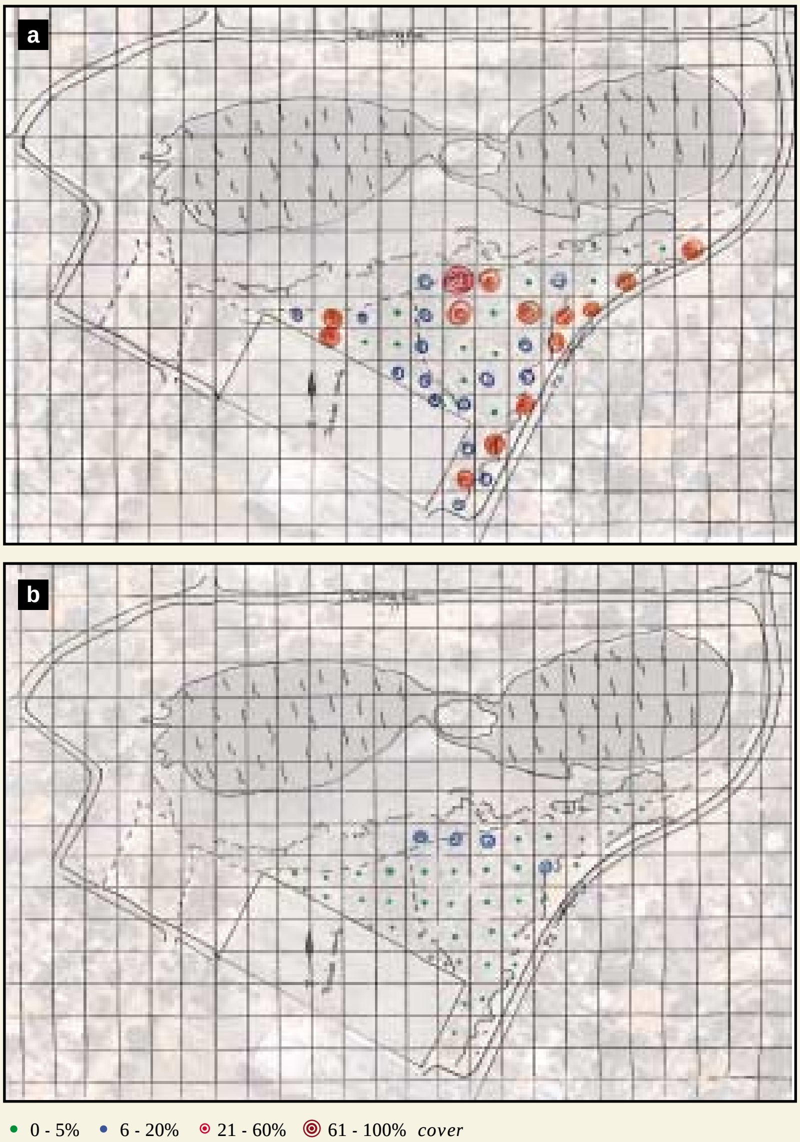


Figure 1. Perennial Veldgrass density and distribution at Blue Gum Lake in 1999 (a) and 2001 (b).

Figure 2. One of the 2 m x 2 m plots set up to monitor the Perennial Veldgrass control program at Blue Gum Lake

In 1998 the spray contractors were not available to treat the grass until early September – well past the peak growth period and after the plants had begun to flower. The kill rate was disappointing and not surprising given that Fusilade® should be applied pre-boot stage. This was discussed with the contractors who agreed to address the matter. In 1999 the contractors sprayed in June, which is too early! It was not until 2000 that the plants were sprayed at the correct time – just before flowering, in mid July. Research at Kings Park, Perth, has shown how crucial timing is for the control of Perennial Veldgrass (Dixon 1998a). It is important to wait until the majority of the new season's adventitious buds are actively growing to allow sufficient herbicide to be taken into the plant, but not leave it so long that flowering has begun. The results from monitoring plots provided the evidence to both contractors and local council about the importance of timing (Figure 3(a)).

Results from counts of seedlings showed the expected high numbers following the wildfire in the year previous to the trials (Figure 3(b)). Fire is known to enhance germination of Perennial Veldgrass seed (Milberg and Lamont 1995, Myut 2001). The much lower numbers in the control plots in subsequent years suggests that Veldgrass recruitment may be density dependent, competition from the resprouting adults limiting seedling establishment.

Less obvious were the changes in species composition. In terms of presence or absence there were no apparent differences between control and treatment plots. Ursinia (*Ursinia anthemoides*) increased in cover in the last year (2001), but observations from other bushland sites in the Perth area suggest this was a good year for the weed. Flatweed (*Hypochaeris glabra*) cover

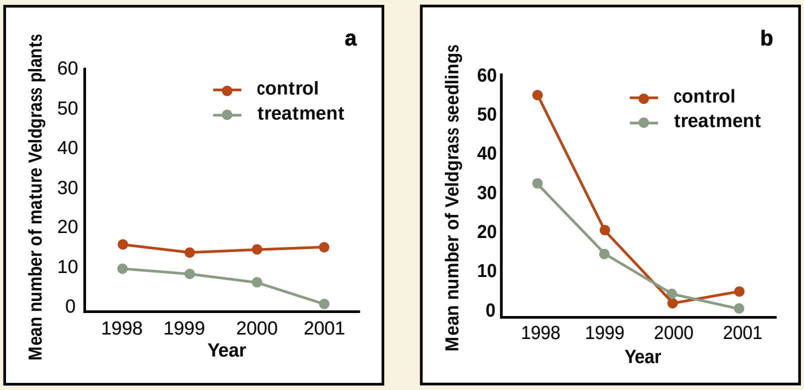


Figure 3. Mean number of mature Perennial Veldgrass clumps (a) and Perennial Veldgrass seedlings (b) in control and treatment plots at Blue Gum Lake from 1998 to 2001.

fluctuated throughout the period and all other weeds reduced in cover or remained similar. There was no influx of weeds following the Veldgrass removal which was encouraging – but nor was there an increase in native germination.

The impacts of grass-specific herbicides on native plant communities are thought to be minimal. The sedges, rushes and many geophytes (orchids, native lilies, etc.) which are monocots like grasses, may however be particularly susceptible. From monitoring of plots at Blue Gum Lake it appears that Fusilade® applied between June and September, has little impact on a range of native species (Table 1).

Table 1. Native species occurring in the monitoring plots unaffected by the Fusilade® treatment.

Annual herbs
Crassula colorata
Homalosciadium homalocarpum
Lobelia tenuior

Perennial herbs
Conostylis aculeata
Desmocladus fasciculatus
Desmocladus flexuosa
Dianella revoluta
Isotropis cuneifolia
Lepidosperma angustatum
Lepidosperma spp
Lomandra caespitosa
Lomandra hermaphrodita
Lomandra preissii
Lomandra sp.
Lyginia barbata
Opercularia vaginata
Patersonia occidentalis
Phlebocarya ciliata
Schoenus curvifolius
Tricoryne elatior

Perennial herbs-geophytes
Burchardia congesta
Caesia micrantha
Drosera menziesii ssp *menziesii*
Microtis media
Pyrorchis nigricans
Sowerbaea laxiflora
Thysanotus manglesianus

Perennial grasses
Austrodanthonia caespitosa
Austrostipa compressa

Shrubs
Acacia stenoptera
Bossiaea eriocarpa
Dampiera linearis
Dasypogon bromeliifolius
Eriostemon spicatus
Eucalyptus calophylla
Gompholobium aristatum
Gompholobium tomentosum
Hardenbergia comptoniana
Hibbertia hypericoides
Hibbertia racemosa
Hovea pungens
Hovea trisperma
Hypocalymma robustum
Jacksonia furcellata
Kennedia prostrata
Lechenaultia floribunda
Leptomeria empetriformis
Macarthuria australis
Petrophile linearis
Pimelea rosea

Chapter 3 **Grass Weeds Management Table**

Species	Common name	Lifeform	Growth form	Photosynthetic pathway	Staggered germination	Growing season	Flowering	Reproductive unit	Dispersal agent	Seedbank persistence (years)
Alopecurus myosuroides	Slender Foxtail	a	c	C3		win-spr	spr	seed	mammal	4+
Ammophila arenaria	Marram Grass	p	r	C3		spr?	spr-sum	rhizome (seed)	water, wind, mammal	(some seed/seed sterile?)
Anthoxanthum odoratum	Sweet Vernal Grass	p	r/c	C3		win-spr	spr-sum	seed, rhizomes	water, wind, bird, mammal, slash	short-med-long?
Arundo donax	Giant Reed	p	r	C3		spr-aut	sum	rhizomes, (seed)	water (bird, wind)	(rarely seeds)
Avena barbata	Bearded Oat	a	c	C3	no	win-spr	spr	seed	mammal, wind	3+ (shorter unburied)
Avena fatua	Wild Oat	a	c	C3	yes	win-spr	spr	seed	mammal, wind	10 (shorter unburied)
Axonopus compressus	Broad-leaved Carpet Grass	p	r/s	C4		spr-sum	sum-aut	seed, stolon	wind	short
Brachypodium distachyon	False Brome	a	c	C3		aut-win	spr	seed	mammal, wind	
Briza spp (*B. maxima, B. minor*)	Blowfly Grass	a	c	C3	no	late aut-win	spr	seed	water, wind, mammal, slash	3
Bromus diandrus	Great Brome	a	c	C3		win-spr	spr	seed	mammal, wind	short
Bromus hordeaceus	Soft Brome	a	c	C3		win-spr	spr	seed	mammal, wind	short
Bromus rigidus	Rip Gut	a	c	C3		win-spr	spr	seed	mammal, wind	short?
Cenchrus ciliaris	Buffel Grass	p	c	C4		spr-aut	opportunistic	seed, short rhizome	wind, mammal, water, bird	5+
Cenchrus echinatus	Mossman River Grass	a	c	C4		warmer months	opportunistic	seed	wind, mammal	mod
Cortaderia selloana	Pampas Grass	p	c	C3		win-sum	opportunistic	seed, rhizome	wind, water, slash, mammal	2
Cynodon dactylon	Couch	p	s/r	C4		spr-aut	sum	seed, rhizome, stolon	water, ant, wind, slash,	3-4
Cynosurus echinatus	Rough Dog's Tail	a	c	C3			sum	seed		
Dactylis glomerata	Cocksfoot	p	c	C3		variable	spr-sum	seed, tillers	water, animal, slash,	1-4+
Digitaria ciliaris	Summer Grass	a	c	C4		spr-aut	sum	seed		
Digitaria sanguinalis	Crab Grass	a	c	C4		spr-aut	sum	seed		
Echinochloa crusgalli	Barnyard Grass	a	c	C4		spr-aut	sum	seed	water, bird	1-9+
Ehrharta brevifolia		a	c	C3			spr	seed		
Ehrharta calycina	Perennial Veldgrass	p	c/sr	C3		cooler months	spr (2 flushes)	seed, short rhizome	water, wind, bird, mammal, slash	short-med
Ehrharta erecta	Panic Veldgrass	p	c/sr	C3		slows in hot conditions	spr-sum (all year)	seed, short rhizome	water, wind, bird, slash	short 1yr/long lived?
Ehrharta longiflora	Annual Veldgrass	a	c	C3	yes	aut-spr	win-spr	seed	water, wind, mammal, slash	1+
Ehrharta villosa	Pyp Gras	p	r	C3		spr-sum	spr-sum	rhizome, seed?		med-long?
Eragrostis curvula	African Lovegrass	p	c	C4		warmer months	opportunistic	seed	water, wind, mammal, slash	
Glyceria maxima	Reed Sweet Grass	p	r	C3		spr-aut	sum	seed, rhizome	water	med
Hainardia cylindrica	Common Barbgrass	a	c	C3		win-spr	spr-sum	seed	wind, water, mammal	
Holcus lanatus	Yorkshire Fog	p	c	C3		win-spr	spr-sum	seed	wind, water, mammal	4+
Holcus setiger	Annual Fog	a	c	C3	yes	aut-win	spr	seed	mammal	
Hordeum glaucum, H. leporinum, H. marinum	Northern Barley Grass, Barley Grass, Sea Barley	a	c	C3	yes	aut-win	spr	seed	mammal	2
Hyparrhenia hirta	Tambookie Grass	p	c	C4		warmer months	sum	erratic seeder, tiller		

Lifeform: *a = annual, p = perennial.* ***Growth form:*** *c = caespitose, r = rhizomatous, s = stoloniferous, sr = shortly rhizomatous.* ***Photosynthetic pathway:*** *C3 = cool season grass,* ***C4*** *= warm season grass.* ***Growing season:*** *usual period of active growth.* ***Flowering:*** *period over which grass flowers.* ***Seedbank persistence:*** *length of seed viability in years (where known).*

Fire response	Suggested methods of management and control	References
killed		17, 60, 167, 242
resprouts	Dig out very small infestations; spray with glyphosate 1 % + penetrant.	281, 256, 30, 167, 242
resprouts	Cut out plants, ensure rhizomes are removed; spray with grass-selective herbicide in winter/spring. Follow-up with seedling control.	231, 260, 241, 30, 167, 242
resprouts	Cut down close to ground and paint with neat glyphosate; carefully spot spray regrowth with 1 % glyphosate before 60 cm high (requires 4-6 treatments) **or** Verdict 120® 10 mL/L + wetting agent **or** Fusilade® 10 mL/L + wetting agent.	162, 241, 316, 290, 300, 126, 193, 222, 167, 242
	Spray at 3-5 leaf stage with Fusilade® 10 mL/ 10 L (500 mL/ha) + wetting agent; repeat over following 2 years.	17, 316, 237, 60, 228, 222, 167, 242
	Spray at 3-5 leaf stage with Fusilade® 10 mL/ 10 L (500 mL/ha) + wetting agent; repeat over following 2 years.	17, 316, 237, 60, 228, 222, 167, 242, 156
fire rare in habitat but survives	Spray when actively growing from spring to autumn with 8 mL/L (4 L/ha) Fusilade® +wetting agent.	17, 316, 222, 167, 242
	Prevent seed set. Spray in winter 1 % glyphosate.	60, 222, 167, 242
	Prevent seed set - hand pull or spray at 3-5 leaf stage with Fusilade® 10 mL/ 10 L (500 mL/ha) + wetting agent; repeat for 2 - 3 years.	231, 212, 30, 313, 228, 222,167, 242
	Prevent seed set - hand pull or spray at 3-5 leaf stage with Fusilade®10 mL/ 10 L (500 mL/ha) + wetting agent; repeat following year if required.	154, 300, 60, 228, 167, 242
	Prevent seed set - hand pull or spray at 3-5 leaf stage with Fusilade® 5 mL/10 L (250 mL/ha) + wetting agent; repeat following year if required.	165, 60, 228, 167, 242
	Prevent seed set - hand pull or spray at 3-5 leaf stage with Fusilade® 10 mL/ 10 L (500 mL/ha) + wetting agent; repeat following year if required.	154, 60, 167, 242
resprouts, stimulates seed production	Cut out small populations, entire plants with dormant buds must be removed; spray with Fusilade® 600 mL/ha + wetting agent **or** spot spray with glyphosate 1 %. Follow-up with seedling control.	241, 307, 33, 208, 300, 289, 310, 101,167, 242
	Prevent seed set, spray with Verdict 520® 5 mL/10 L (250 mL/ha) + wetting agent or spot spray with glyphosate 1 %. Follow-up with seedling control.	241, 248, 95, 289, 101, 222, 167, 242
resprouts	Cut out small plants, do not leave uprooted plants lying on ground - they can resprout; remove flower heads - slash/burn clumps and spray regrowth with 1 % glyphosate . Treat young plants with 0.5 % Fusilade® plus spray oil. May require more than one application.	231, 21, 152, 134, 241, 300, 30, 331, 228, 222,167, 242
resprouts	Solarisation; shade out; spray Fusilade® 5 mL/L + wetting agent in late spring/summer and then in autumn **or** glyphosate 1 %; follow-up always required. Particularly effective after fire.	231, 307, 241, 59, 24, 289, 53, 222, 101,167, 242
	Spot spray 50g 2,2 DPA + wetter in 10 L of water.	222
resprouts, increases	Cut out plants; slash/burn clumps and spray regrowth with glyphosate 1 %. Follow-up with seedling control over following years.	231, 30, 17, 241, 298,167, 242
	Spray 0.5 % glyphosate in spring/summer or Verdict 520® 2 mL/10 L (100 mL/ha) + wetting agent.	241, 222, 247,167, 242
	Spray 1 % glyphosate in spring.	300,167, 242
probably killed	Prevent seed set; intolerant of dense shade; spray Verdict 520® 5 mL/10 L (250 mL/ha) + wetting agent at 3-5 leaf stage up to first tillering.	17, 118, 222,167, 242
	Spot spray 1 % glyphosate.	
resprouts, enhances seed production and germination	Cut out - ensure crown removal; spray with Fusilade® 8 mL/L (4L/ha) + wetting agent - follow-up in subsequent years; utilise unplanned fires and spray regrowth and seedlings within 4-6 weeks. Do not slash.	231, 97b, 216, 102, 289, 68, 167, 242
resprouts, enhances seed production and germination	Cut out small populations removing all rhizomes; spray with Fusilade®; utilise unplanned fires and spray regrowth and seedlings within 4-6 weeks.	231, 210, 167, 242
	Hand pull; spray with Fusilade® 20 mL/10 L + wetting agent before flowering stem emerges; **or** 10 mL/ 10 L (500 mL/ha) at 3-5 leaf stage - secondary seedling flush often occurs - repeat if necessary.	231, 30, 228, 222, 167, 242
resprouts	Spray with Verdict 520® 10 mL/ 10 L (500 mL/ha) **or** glyphosate 1 % + penetrant.	228, 222, 167
resprouts	Cut out small plants; spray with 1 % glyphosate; utilise unplanned fires and spray regrowth at 5-10 cm. Always requires follow-up treatment.	231, 345, 248, 92, 102, 228, 167, 242
resprouts	Spray monocultures with 1 % glyphosate + Pulse® **or** Fusilade® (10 mL/L) + Agral (3.5 mL/L) towards end of summer, respray begining of following summer.	240, 21, 96, 167, 242
		167, 242
	Spray glyphosate 0.5 %	17, 60, 30, 222, 167, 242, 222
	Spray glyphosate 0.5 %	167, 242, 222
	Prevent seed set - hand pull or spray with Fusilade® 10 mL/ 10 L (500 mL/ha) + wetting agent 4-6 weeks after opening rains .	228, 222, 167, 242
resprouts	Cut out small populations - ensure tiller bud removal; spray with 1 % glyphosate between November and March. Spray seedlings at 5 leaf stage with Fusilade® at 20 mL/10 L (1L/ha) **or** slash in spring and spot spray regowth when 15cm high with glyphosate.	247, 313, 209, 167, 242

Grass Weeds Management Table

Species	Common name	Lifeform	Growth form	Photosynthetic pathway	Staggered germination	Growing season	Flowering	Reproductive unit	Dispersal agent	Seedbank persistence (years)
Lagurus ovatus	Hare's Tail Grass	a	c	C3	yes	win-spr	spr-sum	seed	mammal, wind	2-3
Lolium rigidum	Annual Ryegrass	a	c	C3		win-spr	spr-sum	seed	water, wind, mammal	2-4
Lolium temulentum	Darnel	a	c	C3		win-spr	spr-sum	seed	water, wind	
Melinis repens	Natal Redtop	p	c	C4		warmer months	sum	seed		
Parapholis incurva	Coast Barbgrass	a	c	C3		aut-win	spr	seed		
Paspalum dilatatum	Paspalum	p	c/sr	C4		late spr-early aut	sum	seed, short rhizome	animal, water, wind	
Paspalum distichum	Water Couch	p	s/r	C4		spr-aut	sum	stolon, rhizome, seed	water	?
Paspalum urvillei	Vasey Grass	p	c/sr	C4		spr-aut	spr-sum	seed		
Paspalum vaginatum	Saltwater Couch	p	s	C4		spr-aut	sum			
Pennisetum clandestinium	Kikuyu	p	s/r	C4		warmer months	sum	rhizomes, stolons	water, wind	seed rare
Pennisetum macrourum	African Feather Grass	p	c/r	C4		spr-aut	sum	seed, rhizomes, tillers	water, wind	
Pennisetum purpureum	Elephant Grass	p	c/r	C4		spr-aut	spr-sum	rhizomes, tillers, seed?	wind, water, bird	viable seed?
Pennisetum setaceum	Fountain Grass	p	c	C4		spr-aut	spr-sum	seed	wind,water, mammal, slash	6+
Pentaschistis airoides	False Hair Grass	a	c	C3		win	spr	seed		
Pentashchistis pallida	Pussy Tail	p	c	C3		win	spr	seed	wind, ant	
Phalaris minor	Lesser Canary Grass	a	c	C3		win-spr	spr-sum	seed	wind, water, mammal	
Phleum arenarium	Phleum	a	c	C3		win	spr	seed	wind, water	
Phragmites australis	Common Reed	p	r/s	C3		spr-sum	sum	rhizomes, stolons, (seed)	wind, water	establishment rare
Piptatherum miliaceum	Rice Millet	p	c	C3		win-spr	spr-sum	seed	mammal, wind, water	
Poa annua	Winter Grass	a	c	C3	yes	win-spr	spr	seed	wind, water	3
Polypogon maritimus	Coast Beardgrass	a	c	C3		win-spr	spr-sum	seed		
Polypogon monspeliensis	Annual Beardgrass	a	c	C3		win-spr	spr-sum	seed	mammal, wind, water	
Rostraria cristata	Annual Cat's Tail	a	c	C3		win	spr	seed		
Rostraria pumilla	Rough Cat's Tail	p	c	C3		win	spr			
Sorghum halepense	Johnson Grass	p	r	C4		spr-sum	sum	seed, rhizome	explosive, wind, water, bird	5+
Spinifex sericeus	Spinifex	p	s	C4		spr-sum	late spr-sum	stolon, seed?		
Sporobolus africanus	Paramatta Grass	p	c	C4		spr-sum	late spr-sum	seed	wind, water, mammal	
Stenotaphrum secundatum	Buffalo Grass	p	s	C4		less active in winter	sum	rhizomes, stolons, some seed	water	seed rare
Tribolium uniolae	Tribolium	p	c/sr	C3		spr	spr-sum	seed, short rhizome	water, wind, ant	?
Urochloa mutica	Para Grass	p	s	C4		late spr-sum	irregular	stolon, (irregular seeder)	wind, water	(seed set variable)
Vulpia bromoides	Squirrel's Tail Fescue	a	c	C3		win-spr	spr		mammal, water	persistent (med?)
Vulpia myuros	Silver Grass, Rat's Tail Fescue	a	c	C3		win-spr	spr	seed	mammal, water	2-3

Lifeform: *a = annual, p = perennial.* ***Growth form:*** *c = caespitose, r = rhizomatous, s = stoloniferous, sr = shortly rhizomatous.* ***Photosynthetic pathway:*** *C3 = cool season grass,* ***C4*** *= warm season grass.* ***Growing season:*** *usual period of active growth.* ***Flowering:*** *period over which grass flowers.* ***Seedbank persistence:*** *length of seed viability in years (where known).*

Fire response	Suggested methods of management and control	References
	Prevent seed set - spray with 10 mL/ 10 L (500 mL/ ha) Fusilade® + spray oil at 2-8 leaf stage before stem elongation.	60, 30, 228, 222, 167, 242
	Prevent seed set - hand pull or spray with grass-selective herbicide 4-6 weeks after opening rains.	60, 228, 167, 242
	Prevent seed set -spray with 10 mL/ 10 L (500 mL/ha) Fusilade® + wetting agent before stem elongation.	60, 222, 167, 242
	Cut out small populations. Spray 8 mL/L (2-4L/ha) Fusilade® + wetting agent.	60, 241, 101, 167, 242
	Cut out small populations - ensure rhizome removal; spray with grass selective herbicide **or** cut near ground level and immediately wipe with 10 % glyphosate **or** spray adult plants10 mL/L Fusilade + wetting agent. Follow-up seedling control - spray 1 mL/L Fusilade® + wetting agent.	231, 96, 247, 241, 222, 167, 242
resprouts	Spray with glyphosate 1 %, 2-3 sprays over single growing season. Plant weed break to block spread into at risk habitats.	292, 228, 167, 242
	Cut out small populations - ensure rhizome removal; slash and spray regowth with grass-selective herbicide **or** 1 % glyphosate. Follow-up seedling control - spray 10 mL/L Fusilade® + wetting agent.	247, 167, 242
	As for *P. distichium*	
resprouts	Solarisation over warmer months; spray with 1 % glyphosate **or** Fusilade® 10 mL/L + wetting agent, 2-3 sprays over single growing season often required.	231, 241, 21, 247, 53, 228, 167, 242
resprouts	Dig out small infestations; slash winter and/or spray with glyphosate 1 % + penetrant in spring to autumn. Follow up treatment until regrowth ceases follow-up seedling control.	21, 96, 149, 248, 30, 122, 167, 242, 150
resprouts	Dig out small infestations; slash winter and/or spray with glyphosate 1 % + penetrant in spring to autumn. Follow up treatment until regrowth ceases follow-up seedling control.	241, 167, 242
resprouts	Dig out small infestations; slash winter and/or spray with glyphosate 1 % + penetrant in spring to autumn. Follow up treatment until regrowth ceases follow-up seedling control.	314, 241, 26, 102, 53, 190, 167, 242
		60, 167, 242
	Prevent seed set - cut out or spray with grass-selective herbicide.	60, 167, 242
	Prevent seed set - Spray 5 mL/L Fusilade® + wetting agent.	60, 167, 242
		60, 167, 242
resprouts	In summer dry areas, slashing over succesive years reduces biomass; spot spray with glyphosate.	60, 167, 129, 242, 315
	Cut out young plants, slash larger clumps and spot spray with glyphosate.	60, 167, 242
		60, 167, 242
	Spot spray 1 % glyphosate.	167, 242, 222
	Spot spray 1 % glyphosate.	60, 167, 242, 222
		167, 242
		167, 242
resprouts	Spray during first 2 weeks of season's growth - glyphosate 1 % (during summer); **or** 8 mL/10 L (400 mL/ha) Verdict 520® + wetting agent; avoid soil disturbance; follow-up with spot sprays and seedling control.	167, 234, 53, 21, 16, 293, 78, 53, 222, 242
resprouts		167, 242
resprouts	Cut and bag seed head then dig out; slash large clumps in winter/spring and spray regrowth with glyphosate at label ra tes (summer/autumn).	167, 300, 27, 242
resprouts	Solarisation over warmer months; spray with glyphosate 1 %, 2-3 sprays over single growing season **or** 8 mL/L (4 L/ha) Fusilade® + wetting agent. Plant weed break to block spread into at risk habitats.	167, 231, 21, 228, 222, 242
resprouts	Spot spray with glyphosate 10 mL/L **or** Fusilade® 12 mL/L + wetting agent prior to boot stage. Spot spray resprouting clumps and blanket spray seedling flushes with Fusilade® 10 mL/L + wetting agent.	167, 43, 242
resprouts	Spray with 2 % glyphosate.	167,241, 300, 289, 242
	Prevent seed set - hand pull, spray with Select® 10mL/ 10 L (500 mL/ha) (resistant to 'fops' group of herbicides) prior to boot stage.	228,167, 242
seed survives most fires	Prevent seed set - hand pull, spray with Select® 10 mL/ 10 L (500 mL/ha) (resistant to 'fops' group of herbicides) prior to boot stage.	309, 228, 242

Chapter 4 Corms, Bulbs and Tubers

The Weeds that Die Back to Fleshy Underground Storage Organs

Dying back to underground storage organs is a strategy to avoid drought and fire and to cope with low-nutrient soils (Raunkaier 1934, Pate and Dixon 1982, Ruiters *et al.* 1993). This strategy is employed by plants of Mediterranean ecosystems across the world and these plants are known as geophytes. Around 95 % of geophytes introduced to south west Australia come from the Cape Region of South Africa. Pre-adapted to the Mediterranean climate, the nutrient-poor soils and relatively frequent fires of south west Western Australia, they pose a serious threat to bushland in the region. The ability to invade relatively undisturbed bushland makes them a particularly serious group of environmental weeds.

Geophyte weeds can be found invading a range of plant communities and conservation reserves across the Swan Coastal Plain and Jarrah Forest. On the Spearwood dunes at Shenton Bushland Freesia (*Freesia alba* x *leichtlinii)*, Yellow Soldier (*Lachenalia reflexa*), Watsonia (*Watsonia meriana*) and Pink Gladiolus (*Gladiolus caryophyllaceus*) are all serious invaders of relatively undisturbed Banksia woodland. On the heavier winter wet soils at Brixton Street Wetlands, Harlequin Flower (*Sparaxis bulbifera*) and a number of *Watsonia* species are widespread in the wetland and a serious threat to the diverse native herblands. Babiana (*Babiana angustifolia)*, Hesperantha (*Hesperantha falcata)*, One Leaf Cape Tulip (*Moraea flaccida*) and Black Flag (*Ferraria crispa*) are all present in small populations on the disturbed edges. At the foot of Darling Scarp, in the Talbot Road Bushland, Harlequin Flower, Freesia and Bulbil Watsonia (*Watsonia meriana* var. *bulbillifera*) are invading undisturbed Marri and Banksia woodlands, displacing the native herbs that make up much of the understorey. Just north of Perth along the edges of the Gingin Brook, Arum Lily (*Zantedeschia aethiopica*) and Taro (*Colocasia esculenta*) are a serious threat to the last remaining patches of Swamp Paperbark *(Melaleuca rhaphiophylla*) and Flooded Gum (*Eucalyptus rudis*) woodlands. Most of these bushlands are listed as regionally significant and some support rare and threatened flora and threatened plant communities. Geophyte weeds are one of the greatest threats to their conservation values.

This chapter deals with the weedy geophytes as a group as they often share common life-cycles and similar reproductive biology. This in turn often relates to similar control methods and management strategies.

A single plant of Watsonia meriana *on the edge of shrublands in Talbot Road Bushland.*

In this chapter the life-cycles and reproductive biology of the corms, the bulbs and then the tubers are described. How this relates to their dispersal, spread, establishment and persistence over time is covered next. Towards the end of the chapter detailed case studies illustrate how all this information relates to management and how it can be used to control these weeds where they are invading particular bushlands. Finally a table of available control and management information for 57 species of geophyte weeds is presented.

The underground storage organs; life-cycles and reproduction

The underground storage organs of these weeds fall into three categories; corms, bulbs or tubers – depending on the plant part that is modified to make up the storage organ. Understanding their life-cycles and reproductive biology is an important part of knowing how to prevent spread and control these sometimes indefatigable invaders.

The corms

Corms comprise underground swollen stems or stem bases. The following naturalised genera *Babiana*, *Chasmanthe*, *Freesia*, *Gladiolus*, *Hesperantha*, *Watsonia*, *Moraea*, *Sparaxis* and *Ferraria* all die back to corms over summer.

Life-cycles

Almost without exception the weedy cormous plants in south west Western Australia are summer-dormant sending up their first shoots as the temperatures drop with the autumn rains. Almost all have annually renewed corms (Du Plessis and Duncan 1989). That is, each year a new daughter corm, sometimes two, is formed as the plant is actively growing. Meanwhile the parent corm slowly exhausts and dies. Sometimes the remains of the parent can be observed as a series of plates below large old corms of Watsonia or woody tunics on corms of Hesperantha.

Black Flag is an interesting exception. It has a column of persistent perennial corms to which a new corm is added each year (Box 4.1). Taro, a native of southeast Asia, is another exception. It grows actively through summer and has a perennial corm. Although dormant through winter it doesn't always lose its leaves.

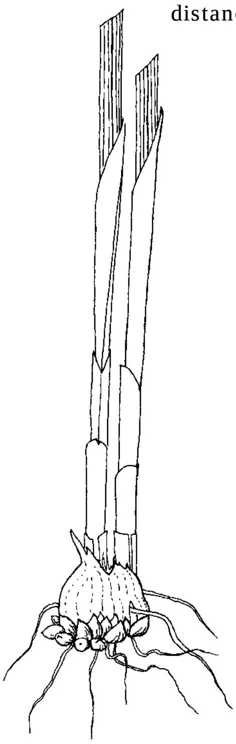
Reproduction

Cormous weeds are able to reproduce vegetatively in a variety of ways.

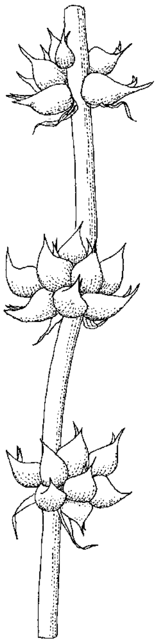
- Two or more daughter corms from the one parent corm.
- Axilliary buds formed on parent corms that go to produce new plants when the growing shoot is removed.
- Tiny 'seed like' cormels produced around the base of the parent corm or along stems.

Most species also reproduce by seed and seed and cormels are the main mechanisms for medium to long distance dispersal.

Freesia forming stem cormels just after flowering in late spring/early summer.



Basal cormels on Wavy Gladiolus (Gladiolus undulatus).



Stem cormels on Bulbil Watsonia in late spring, after flowering.

Chapter 4 Corms, Bulbs and Tubers

The bulbs

Bulbs are made up of swollen leaf bases. They form the underground storage organs for many common weeds such as *Amaryllis*, *Allium*, *Lachenalia* and *Oxalis*. The bulbs of *Lachenalia*, *Oxalis* and *Allium* are annually renewed while others such as *Amaryllis* are perennial.

Life-cycles

Most bulbous weeds are summer dormant, sending up leaves as the temperatures drop with the first autumn rains. Flowering and seed set take place at the end of the growing season, in winter to late spring. There are exceptions though. The flowers of Easter Lily (*Amaryllis belladonna*) and some others in the family Amaryllidaceae emerge in early autumn, often long before the first rains with the leaves appearing after flowering is finished.

Reproduction

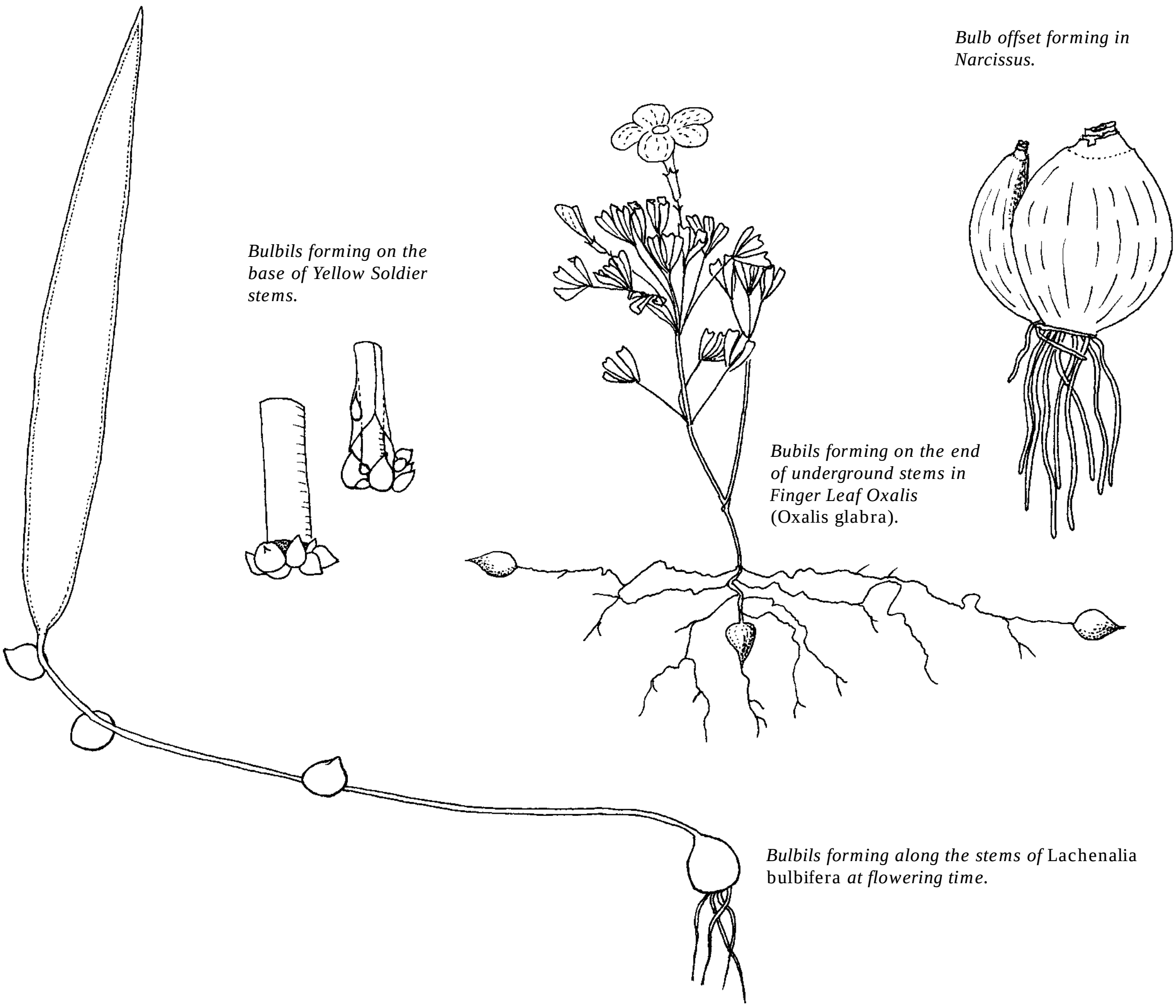
Bulbous weeds reproduce vegetatively in a number of ways.

Perennial bulbs such as *Amaryllis* and *Narcissus* produce offsets or daughter bulbs each year.

Oxalis produces new bulbs and bulbils that arise from nodes along underground stems.

Lachenalia bulbifera, as the name suggests, has a frightening capacity to reproduce from bulbils formed around the base of the bulb, along underground stems and even along the base of leaves left lying around. *Lachenalia refexa* (Yellow Soldier) has also been observed to produce bulbils on the base of leaves and flowering stems that have become separated from the bulb.

Most bulbous weeds produce large amounts of seed each year and seed appears to be a major mechanism for dispersal into relatively undisturbed bushland.



Bulb offset forming in Narcissus.

Bulbils forming on the base of Yellow Soldier stems.

Bubils forming on the end of underground stems in Finger Leaf Oxalis (Oxalis glabra).

Bulbils forming along the stems of Lachenalia bulbifera *at flowering time.*

The tubers

Tubers generally comprise swollen underground stems or roots. *Asparagus* (*A. asparagoides* - Bridal Creeper, *A. declinatus* - Bridal Veil, *A. densiflorus* - Asparagus Fern and *A. scandens* - Climbing Asparagus) arise from rhizomes (underground stems) supported by a dense tuberous root mat. Arum Lily arises from a large tuberous root sometimes referred to as a rhizomatous tuber.

Life-cycles

The species of *Asparagus* that occur as weeds in bushland around Perth are all dormant over the summer months with active growth triggered by falling temperatures and the first rains in autumn.

Arum lily will retain green leaves year round if there is sufficient water available. On drier sites it goes into dormancy over summer.

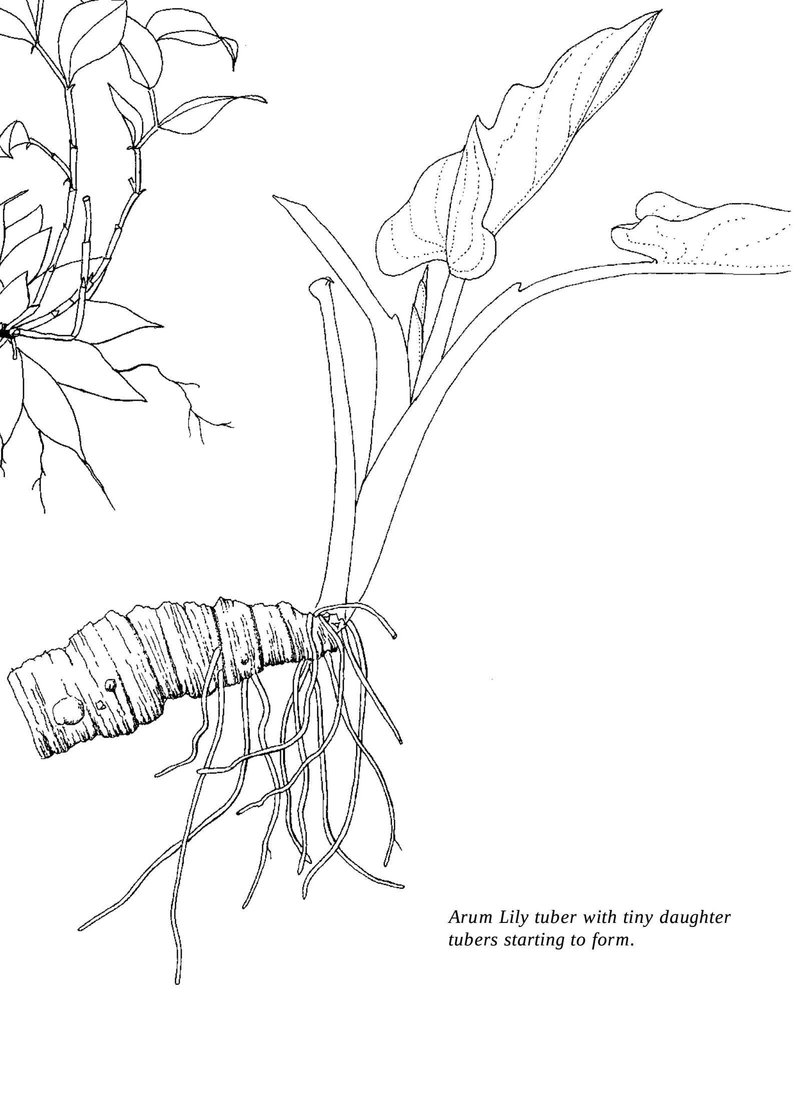
Reproduction

Vegetative reproduction in Bridal Creeper is via yearly expansion of rhizomes supported by a perennial tuberous root mat. The mat is usually five to ten centimetres below the soil surface and up to 10 centimetres thick. The rhizomes have a series of shoot buds along their length and new shoots always arise from the rhizome, never directly from a tuber. This bud bank confers local persistence and an ability to withstand disturbance (Willis 2000).

The perennial tubers of Arum Lily produce offsets throughout the growing season. Spread in this way is very localised, less than 30 centimetres per year (Moore 1997).

Both Arum Lily and Bridal Creeper produce large amounts of viable seed each year.

Perennial tuberous root mat of Bridal Creeper with a shoot coming from the rhizome.



Arum Lily tuber with tiny daughter tubers starting to form.

Spread into undisturbed bushland

Most bulbous and cormous species originally establish at bushland sites via dumped garden rubbish or soil. Once established, production of daughter corms or bulbs, unless there is extensive soil movement, only allows for local expansion of existing populations. Seed provides the major mechanism for medium to long distance dispersal into undisturbed bushland.

The seeds of species such as *Freesia*, *Sparaxis* and *Lachenalia* have no specialised adaptation for dispersal, relying mainly on water or soil movement. *Gladiolus*, and to a lesser degree *Watsonia*, with their winged seeds, can also rely on wind for medium to long distance dispersal (Goldblatt 1989, Goldblatt and Manning 1998). The widespread distribution of Pink Gladiolus throughout bushland around Perth is often a reflection of its predominantly wind dispersed seed.

Fire appears to play a major role in the seedling establishment of many of these species, facilitating the expansion of populations into otherwise intact bushland (Box 4.2).

For those species that do not set seed, movement into relatively undisturbed bushland is reliant on soil disturbance. Soursob (*Oxalis pes-caprae*), Finger Leaf (*O. glabra*) and Four O'Clock (*O. purpurea*) rarely set seed in the Perth area. Spread is almost entirely dependent on movement of bulbs or bulbils. Left undisturbed Soursob will only spread around ten centimetres per year (Parsons and Cuthbertson 2001). Consequently these weeds often occur on the degraded edges of bushland and, without soil disturbance, rarely spread into intact areas.

The tiny cormels produced around the base of cormous species such as Wavy Gladiolus (*Gladiolus undulatus*) and around the base and in the leaf axils of Two Leaf Cape Tulip (*Moraea miniata*), also provide a mechanism for medium to long distance dispersal and for spread into undisturbed bushland. This can be via water, soil movement, birds and human activity.

Birds are the agents of medium to long distance dispersal of the fleshy berries of Arum Lily and the small red berries of Bridal Creeper and the major mechanism for establishment of new populations in undisturbed areas (Stansbury 1996, Moore 1997). Water flow and, for Arum Lily, foxes (ingesting seed), also play a role.

Persistence of propagules

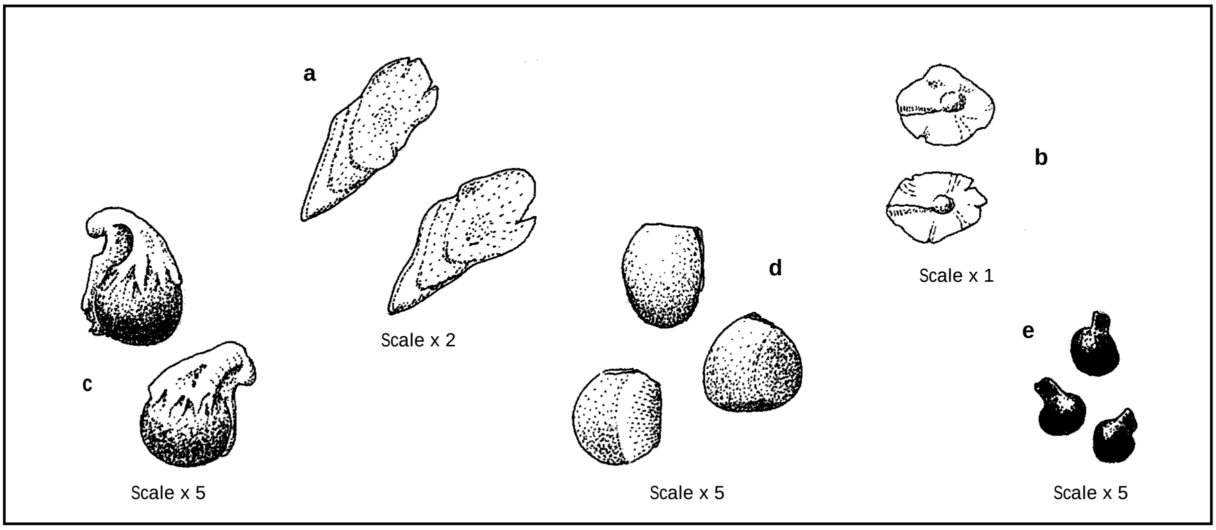
The seeds

Among natural populations within the Cape Region of South Africa, the seeds of most geophytes do not display dormancy and do not require fire-related cues (smoke or heat) to germinate (Keeley and Bond 1997). Interestingly horticulturists have found that with very few exceptions the seed of South African geophytes germinate easily, most in the first season after ripening (Du Plessis and Duncan 1989).

The seed contained within the fleshy berries of Bridal Creeper generally germinate or decay within two years (Raymond 1996) and those of Arum Lily in less than six months (Panetta 1988).

Observations in bushland around Perth certainly suggest that, for many species, most seed germinate in the first winter after ripening. Each year carpets of seedlings can be observed among invading populations of *Freesia*, *Sparaxis*, *Lachenalia*, *Romulea* and some species of *Gladiolus*. However in a season immediately following any control program where seed set is prevented, few seedlings can be observed. So once adult plants have been controlled follow-up work on seedlings could be over in a few short years. There are bound to be exceptions though.

Effective management will rely on detailed information and research on individual species. In the meantime it is important to remain vigilant for at least five years following initial control of adult plants.



Seeds of a) Watsonia, b) Pink Gladiolus, c) Freesia, d) Harlequin Flower, e) Yellow Soldier.

Box 4.1 Black Flag – a growing concern

Black flag (*Ferraria crispa*) has been around as a garden escape in the Perth area for more than 100 years. It was first collected by the botanist Alexander Morrison from 'east of Perth' in 1898. It is now naturalised on sandier soils in Banksia and Tuart woodlands from Perth around the coast to Busselton, in Karri forest around Augusta and on sandier soils in *Agonis* woodlands near Albany. It has also been recorded from roadsides in the Wheatbelt, 100 km east of Perth, near Cunderdin (Western Australian Herbarium 1998).

Currently Black Flag grows mainly in discrete patches on the disturbed edges of bushland and along roadsides. Spreading both by corms and seed, occasional infestations can be found in the middle of relatively undisturbed areas. Once established in bushland it can form dense monocultures excluding most native flora.

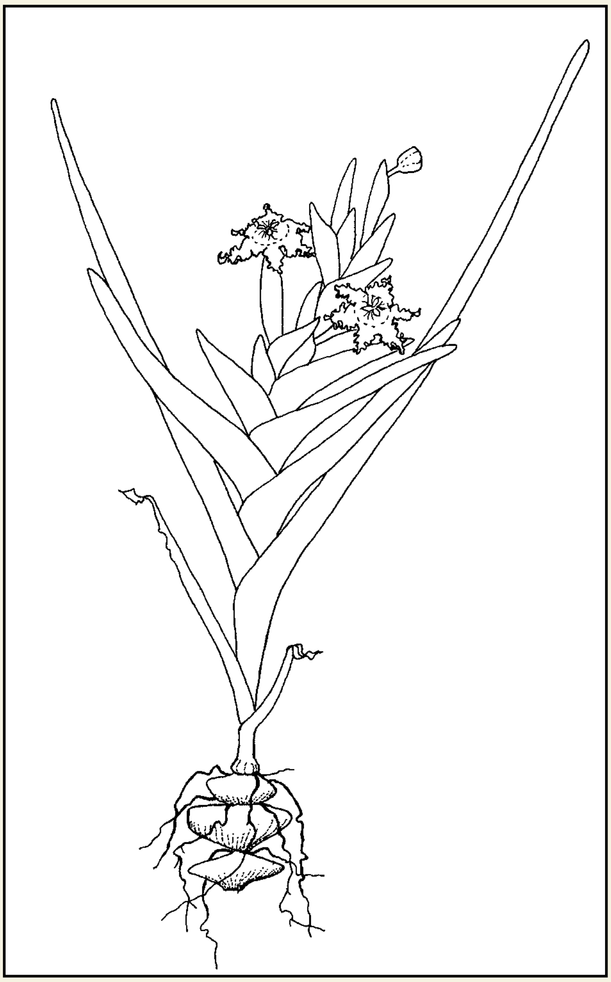
The unusual biology of Black Flag makes it of particular concern to anyone trying to protect native plant communities from exotic invaders.

Each year plants produce a new corm that is added to a column of dormant, previous years' corms. In evolutionary terms the column is thought to be half way between a corm and a rhizome (Du Plessis and Duncan 1989).

- Any herbicide application appears to knock only the present and sometimes the previous year's corm, leaving all others intact.
- The next corm down in the column generally sprouts the following year.
- Herbicide does not appear to be translocated between corms in the columns.
- If one of the dormant corms in the column is dislodged it will sprout and go on to produce a new plant.
- Large amounts of seed are produced in late spring.

Preventing Black Flag from becoming wide-spread in bushland in the short term is going to depend on careful physical removal of small infestations as soon as they become apparent, or, for large infestations, repeated herbicide application over many years. Research into the biology of Black Flag and management options are urgently required.

For small infestations (approx 2 m x 2 m) on the disturbed edge of bushland think seriously about physical removal. But be warned – if extreme care is not taken your efforts could result in spreading Black Flag even further. You may need to sieve soil to get all corms and the level of soil disturbance will be extreme. All material will require very deep burial (more than a metre) away from your bushland site. Place excavated material in a 'tough garden bag' and send to the local tip for deep burial.



The vegetative parts – corms, bulbs, tubers, offsets, cormels and bulbils.

Vegetative material can sometimes have greater persistence in the soil than seed. The cormels of Two Leaf Cape Tulip are known to remain viable in the soil for at least eight years (Parsons and Cuthbertson 2001) and cormels from Bulbil Watsonia also remain viable for many years (Lamp and Collet 1989).

Corm dormancy has been reported in *Moraea*, *Gladiolus* and *Watsonia* (Box 4.2). You may think you have the weed under control when in fact there is a population of dormant corms lying just beneath the soil surface waiting for the next fire or other suitable conditions to stimulate active growth.

For many species that arise from corms or produce bulbils or cormels, follow-up work could be required for several years.

Box 4.2 Fire and the geophyte weeds

Fire is the major disturbance in the Mediterranean ecosystems of South Africa from where 95 % of our bulbous and cormous weeds have come. Consequently many have evolved life history traits that are strongly tied to recurrent fire.

Mechanism for survival

Dying back to an underground storage organ over the long dry summer is an extremely effective way of surviving fire. Soil offers very effective insulation to the corms or bulbs and some have contractile roots that pull the storage organs of young plants deeper into the soil helping avoid lethal fire temperatures (Bond and van Wilgen 1996). When dormant in summer, most cormous, bulbous and tuberous weeds will probably survive all but the very hottest fires.

Pink Gladiolus flowering in the spring season following a summer fire in Banksia woodland at Shenton Bushland.

Dormancy and fire-stimulated flowering

Some cormous and bulbous weeds, to varying degrees, are dormant between fires and sometimes between seasons. That is, the corms remain dormant in the soil producing no leaves or flowers during the growing season. Within Cape Tulip populations, for example, up to 60 % of corms may be dormant in any one season. Fire often brings most corms out of dormancy but seasonal conditions including soil temperature and rainfall also play a role (Parsons and Cuthbertson 2001).

Others flower particularly well following fire with fire-stimulated flowering commonly observed among many geophytes where they occur naturally in southern Africa (Goldblatt 1978, Richardson *et al.* 1984, Le Maitre and Brown 1992). Nearly all species of *Watsonia* flower profusely following veld fire (Goldblatt 1989). Some, such as *Watsonia borbonica,* only flower for the first few seasons following fire (Le Maitre 1984). This mass flowering corresponds with prolific seed production. Displays of *Gladiolus* are also striking in the first few seasons following a burn, particularly in the winter rainfall areas on the nutrient-poor sandstone soils of the Cape Region (Goldblatt and Manning 1998). It is also interesting to note that horticulturists commonly use smoke to induce flowering in South African geophytes with *Narcissus tazetta*, *Freesia* and *Crinum* species all responding favourably (Tompsett 1985, Mathew 1997).

Fire-stimulated flowering also appears to occur to some degree among populations of these plants where they are invading the Mediterranean ecosystems of southern Australia. Interestingly both corm dormancy and fire-stimulated flowering have been recorded in Pink Gladiolus invading Banksia woodland near Perth (Marshall 2001). In the first season following fire workers recorded a mean of 42 flowering plants per one metre square plot. Two years after the fire a mean of only 2.6 flowering plants was recorded. The total number of plants (flowering and non-flowering combined) decreased from a mean of 54 per plot to 7 plants per plot. This work indicates that most corms of Pink Gladiolus seem to go into dormancy between fires. How wide-spread the phenomenon is among weedy geophytes requires further investigation as it has important implications for management and control of cormous and bulbous weeds.

Seeds, seedlings and spread

Generally the seeds of these plants do not require the smoke or heat of fire for germination. Rather, it is thought that the fire-stimulated flowering is actually linked to favourable post-fire conditions. For cormous and bulbous plants the post-fire environment offers space and light for seed germination and seedling establishment in the absence of larger trees and shrubs (Keeley and Bond 1997, Goldblatt and Manning 1998).

With mass flowering and prolific seed production followed by favourable conditions for seed germination and seedling establishment, fire appears to be one of the major factors facilitating the establishment of many of these weeds into otherwise undisturbed bushland.

A window of opportunity

Fire however also offers a significant opportunity to control bulbous, cormous and tuberous weeds in bushland. Following a summer fire these weeds will often emerge in autumn, prior to regeneration of native vegetation. The plants are clearly visible and the resprouting flowering bulbs, corms and resprouting tuberous mats of bridal creeper are an easy target for herbicide control. Control of established populations and prevention of seed production and further spread are achievable. It is an ideal time to control those species such as Cape Tulip and Pink Gladiolus that are largely dormant between fires.

Additional resources should always be made available to control bulbous, cormous or tuberous weeds following fire.

Management and control

Stopping the spread

- Understand the distribution of the weed across the bushland by mapping the spread. This is an important first step (chapter 7). Maps are the basis for any strategy to limit further spread and contain existing populations.
- Target small populations in good bush and the outliers of dense infestations (use the maps).
- Determine if paths and water run-off are contributing to spread of cormels, bulbils or seed.
- Determine whether the sources of infestations are old soil or rubble dumps. Sometimes the only option may be physical removal of these dumps (Box 4.3).
- Avoid removing plant material at times of seed or cormel production.
- Avoid working in areas where weeds are actively shedding seed.
- Control in the season immediately following fire will prevent seed set in established plants, reduce seedling establishment in the post fire landscape and prevent expansion of existing populations.

Physical removal

Although hand-removal can be very labour intensive and ties up a lot of resources it is often the most appropriate and sometimes the only method of control available. It is particularly appropriate for small isolated populations in good bushland.

Targeting these isolated populations of weeds in good bushland and preventing their establishment and spread is the key to protecting undisturbed plant communities.

Minimising soil disturbance

Physically removing weeds with fleshy underground storage organs requires extreme care in handling. Soil disturbance can lead to the establishment of other weeds, particularly annual herbs (Hobbs and Atkins 1988, Hobbs 1991). In Shenton Bushland the soil disturbance caused by physical removal of Yellow Soldier bulbs caused an increase in the cover of annual weeds such as Flat Weed (*Hypochaeris glabra*) and French Catchfly (*Silene gallica*). To try and minimise soil disturbance a range of tools are used for physically removing bulbous, cormous and tuberous weeds. Such tools include sharp knives, long screwdrivers and narrow trowels for smaller plants such as Freesia and Harlequin Flower and specially designed 'Peter levers' for Watsonia and Arum Lily.

Box 4.3 Dealing with sources of weed invasion into undisturbed bushland.

Old rubble/garden refuse dumps throughout Shenton Bushland appear to be one of the major sources of cormous and bulbous weed invasion into undisturbed bushland. In late winter 2000 the Friends, City of Nedlands with a group of community service workers, Green Corps and EWAN, removed one such dump that appeared to be the source of Freesia invasion into the Banksia woodland at Shenton Bushland. The operation took five working days and involved moving around 30 cubic metres of rubble, taken away for deep burial at a tip site.

The remaining bare ground was direct seeded with species of native herbs, shrubs and a few trees. The seed was collected from adjoining Banksia woodland. The following autumn Slender Podolepis (*Podolepis gracilis*), Prickly Moses (*Acacia pulchella*), Native Wisteria (*Hardenbergia comptoniana*) and Jarrah (*Eucalyptus marginata*) were among the species germinating on the removal site. A few annual weeds were also present.

Green Corps team starting to remove the soil dump .

The site on completion of removal.

Timing is everything

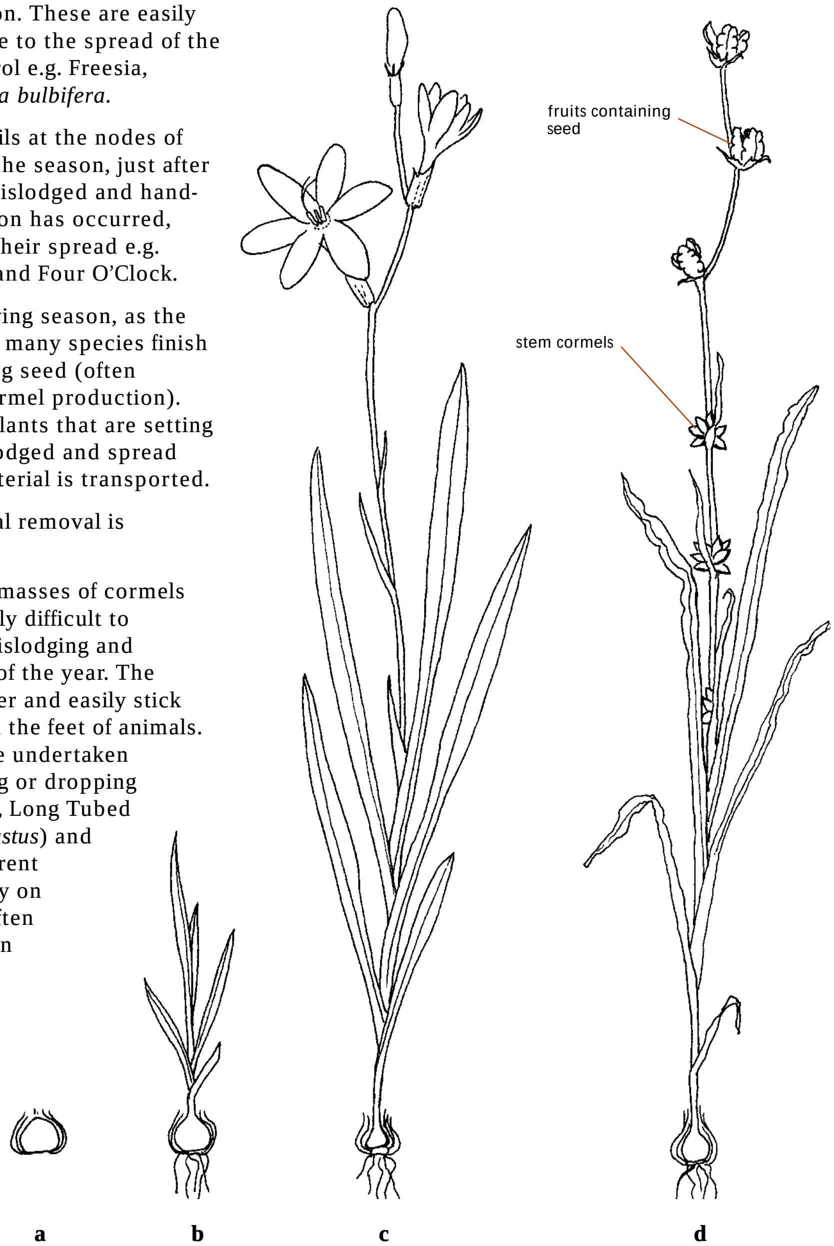
Understanding the life-cycle of the weedy geophytes over the growing season can mean the difference between effective control and unwitting spread. For many species hand-removal should only be carried out early in the growing season.

- Late in the growing season specialised roots (known as contractile roots) drag annually renewed corms or bulbs deeper down into the soil. For the relevant species hand-removal is much easier and causes a lot less soil disturbance if undertaken early in the growing season e.g. *Freesia*, *Sparaxis* and *Watsonia*.
- Stem cormels and bulbils are produced towards the end of the growing season. These are easily dislodged and can contribute to the spread of the weed you are trying to control e.g. Freesia, *Sparaxis bulbifera*, *Lachenalia bulbifera*.
- *Oxalis* species produce bulbils at the nodes of underground stems later in the season, just after flowering. These are easily dislodged and hand-removal, after bulbil formation has occurred, will generally contribute to their spread e.g. Soursob, Finger Leaf Oxalis and Four O'Clock.
- Towards the end of the growing season, as the days get longer and warmer, many species finish flowering and start producing seed (often coincides with bulbil and cormel production). When physically removing plants that are setting seed ensure seed is not dislodged and spread through the bushland as material is transported.

For the following species physical removal is hazardous at any time.

- Those species that produce masses of cormels around the base are extremely difficult to physically remove without dislodging and spreading cormels any time of the year. The cormels are tiny, float in water and easily stick with mud to boots, tools and the feet of animals. Physical removal needs to be undertaken in a way that avoids releasing or dropping cormels. e.g. Wavy Gladiolus, Long Tubed Painted Lady (*Gladiolus angustus*) and Two Leaf Cape Tulip. The parent corm often confers dormancy on cormels and its removal is often followed by mass germination of those cormels left behind.
- Arum Lily produces numerous tiny daughter tubers that become dislodged during hand-removal. This appears to happen throughout the growing season.
- The rhizomes attached to the tubers of Bridal Creeper will produce new shoots from any tiny fragments left behind.

Note: *Physical removal of weeds such as Watsonia, Arum Lily or Bridal Creeper on steeper slopes or along creeks and riverbanks can lead to serious soil erosion.*



Harlequin flower (Sparaxis bulbifera)*; a) Summer, dormant corm b) Late autumn, corm begins to sprout c) Early spring, flowering and corm exhaustion d) Spring to early summer, leaves begin to die back, seed and stem cormels are formed.*

Slashing leaves and stems

Repeated removal of leaves and stems of some species of weedy geophytes over time can reduce population density, reproductive output and plant vigour. It is generally labour intensive, however, and often not effective in the longer term. The few examples below illustrate where it can be a useful tool, under certain circumstances.

- If Bridal Creeper is slashed back to the stem bases every month over the growing season for several years plants are severely weakened (J. Moore pers. comm.). In bushland on Garden Island, just off the coast of Perth, continual grazing by Tammar wallabies has prevented Bridal Creeper from becoming wide-spread on the island (Keighery 1993).
- Trials in the fringing vegetation along Bennett Brook in Perth suggested that slashing Arum Lily back to the base every month over the growing season can, in the short term at least, greatly reduce the number of adult plants in a population. Plants were slashed to the base every month for seven months over the 1999 growing season. Over 80 % of plants in the population did not resprout in the 2000 season (Brown unpubl). The slashing was done by hand with a sharp hoe and would be very labour intensive over a broad area. The work would need to continue over a number of years and if left for any length of time populations would probably quickly return to pre-treatment levels.
- Work in South Australia has found if Bulbil Watsonia plants are slashed at 15 centimetres or less above the ground, at the first sign of a flower spike, neither flower spike nor bulbils will be produced in that year. In addition the plant will form smaller corms the following year (Wilson and Conran 1993).

Note: *simply removing flower spikes to prevent seed set can sometimes lead to more vigorous plants the following year. Work on Pink Gladiolus in south west Western Australia found that removal of flowers just as they were opening resulted in a larger replacement corm (and presumably more vigorous plants that would be harder to kill) the following year (Hocking 1992).*

Chemical control methods

Chemical control of bulbous, cormous and tuberous weeds is often the only practical option available for dense infestations invading good bushland. It can be practical on a large scale, avoids soil disturbance and prevents soil erosion.

Herbicide application needs to be done by experienced operators with the correct equipment, knowledge of herbicides and an understanding of bushland and of the native flora. Regardless of the herbicide, application needs to be carefully timed to be effective on many of the species dealt with in this chapter, particularly the annually renewed bulbs and corms (Box 4.4).

Note: *Anyone applying herbicides should have appropriate training in the safe use and handling of relevant chemicals (Chapter 8).*

The herbicides

Important note: *The following herbicides are currently the subject of a minor use off-label permit in non-crop situations in Western Australia. Application must comply with all conditions of the permit. Available from*: (http://permits.nra.gov.au/PER4984.PDF).

Glyphosate

When applied at the correct stage of the life-cycle, this non-selective herbicide has been found to be effective against a number of South African bulbous, cormous and tuberous species. These include Freesia (*Freesia alba* x *leichtlinii*), *Ixia* species (Dixon and Keighery 1995), *Watsonia* (Day 1993) and Bridal Creeper (Pritchard 2002). Glyphosate is an acceptable option where the weeds occur in dense monocultures on the disturbed edges of bushland. However these weeds often grow closely amongst native vegetation and the use of non-selective herbicides can lead to unacceptable off-target damage unless the application method is very carefully targeted (Box 4.2 and Box 4.3).

Metsulfuron methyl

Following the introduction of the sulfonylurea group of herbicides in early 1980s, metsulfuron methyl (Brush-off®, Ally®) in particular has been found to be very effective against a number of South African bulbous/cormous species. These include Soursob (Peirce 1998), Bridal Creeper (Pritchard 1991, Dixon 1996), Freesia (Dixon 1998b), Harlequin Flower (Meney 1999, Brown and Brooks in press c) and Yellow Soldier (Brown *et al.* 2002). Interestingly, some of these studies suggest that many native species are resistant to the effects of metsulfuron methyl at rates of 5 g/ha and below (Dixon 1996, Meney 1999, Moore 1999, Brown *et al.* 2002, Brown and Brooks in press c). This is an area that requires further study and any use of the sulfonylurea group of herbicides in bushland needs very careful consideration. Metsulfuron methyl can remain active in dry alkaline soils and is absorbed by roots for many months following application (Parsons 1995, Noy 1996, Sarmah *et al.* 1998).

Chlorsulfuron

Also of the sulfonylurea group of herbicides, chlorsulfuron (Glean®) is known to be effective on Arum Lily (Moore and Hoskins 1997), Cape Tulip (Parsons and Cuthbertson 2001) and Harlequin Flower (Brown and Brooks 2002). The impacts of chlorsulfuron on native plants that co-occur with these weeds are not well understood. Trials on Harlequin Flower invading herb-rich shrublands in the Brixton Street Wetlands indicated chlorsulfuron had an impact on some native herbs (Brown and Brooks in press c).

Important note*: Both metsulfuron methyl and chlorsulfuron can inflict damage to vegetation at very low concentrations. Both can remain active in the soil for some months following application. They should only be spot sprayed on target species invading native bushland and always by well-qualified responsible operators with a thorough knowledge of the native flora.*

2,2-DPA

Reported to successfully control *Watsonia* invading remnant native vegetation. Sprayed at a rate of 10 g/L, 2,2-DPA has little impact on a range of native species (Moore and Fletcher 1994, Brown and Brooks unpubl.).

Targeted application techniques

Sometimes the only option for effective control is a non-specific herbicide such as glyphosate. The herbicide needs to be carefully targeted so that only the weed, often growing closely amongst native vegetation, is treated. An example of a successful targeted application technique in practice is the effective control of *Watsonia* invading native bushland on the Darling Scarp (Day 1993). Using a 500 mL spray bottle with a sponge wired over the nozzle, a 10 % solution of glyphosate is wiped onto individual leaves just before flowering, at corm exhaustion. Community volunteers have controlled large populations of Watsonia and contained the spread of the weed using this method.

The effectiveness of this treatment was recorded at three bushland sites across the Swan Coastal Plain from 1999-2001 with some interesting results (case study 4.2).

Wiping Watsonia leaves in spring in Shenton Bushland.

For the smaller cormous and bulbous species wiping leaves of individual plants is not practical. In Shenton Bushland for example there were up to 1700 bulbs of Yellow Soldier in a single 2 m x 2 m plot. With limited resources available wiping individual plants was not an option (case study 4.1).

Biological control

Biological control is presently available for Bridal Creeper. In 1999 CSIRO released a leafhopper that weakens the plant by sucking sap, causing a silver patterning on leaves and reducing seed set. It is a very useful tool for preventing the spread of large infestations that are either inaccessible or beyond the resources of current control programs. A rust fungus has been released and is also available for the control of Bridal Creeper. Infected plants shed leaves early and are severely weakened. The rust is slow to spread through established populations of Bridal Creeper.

Recording effectiveness of control methods and regeneration of native plant communities

It is important to have in place objective methods for assessing effectiveness of control methods over time so treatments and management strategies can be adjusted accordingly.

- **Maps of a particular weed species in a patch of bush:** These provide good base line information for a control program, and over time, if updated, will provide a record of the effectiveness of that program.

- **Fixed photo points:** Although an interesting record, fixed photo points do not provide quantitative information on the overall success of the program or the degree of follow-up required. They also provide very limited information on the impact of a control program on the native plant community. As long as the limitations are recognised, photo points can be a useful tool for recording change over time. Photos were particularly useful for recording the highly visable changes that occurred following removal of Taro along the Gingin Brook, (case study 4.3), and for recording the change in *Watsonia* treatment sites, as long as they were accompanied by a detailed species list. They were not so useful for recording change following the removal of smaller cormous weeds such as Harlequin Flower in the diverse plant communities at Brixton Street.

For more information Elzinga *et al.* (2001) provides very detailed information on setting up photo point monitoring and studies where repeat photography has been used to monitor long-term change.

Importantly though, distribution maps and photos will not record in any detail changes in weed populations. Recording the density and frequency of particular weeds from year to year is often vital in assessing the effectiveness of a control program. Also, when undertaking any weed management program in bushland, the focus is not simply on eliminating weeds but on protection of intact native plant communities. It is important to have an understanding of what impacts the control work is having and what moves in once the target weed/s have been controlled. In the incredibly diverse flora of south west Western Australia this can be a complex task. At one site on the eastern side of the Swan Coastal Plain there are over 300 native plant species in only 19 hectares and up to 80 in a 10 m x 10 m plot. It is important to know and understand these systems if they are to be managed effectively for nature conservation. Some methods used to collect information on change over time in populations of weeds that die down to underground storage organs and co-occurring native species are described in case studies on Yellow Soldier (case study 4.1), Watsonia (case study 4.2), Taro (case study 4.3) and Harlequin Flower (case study 4.4).

***Note:** With bulbous, cormous and tuberous weeds, until they begin active growth in the growing season following herbicide application, it is often not possible to know how many plants including the storage organ, have been killed. It may be nine months after treatment before you can assess effectiveness of a control program.*

Key points

- South African geophytes are one of the most serious groups of bushland weeds in south west Western Australia.

- Once established on disturbed edges they can invade relatively undisturbed bushland, generally via seed or cormels, form dense monocultures and displace native plant communities.

- Fire appears to facilitate establishment of seedlings and expansion of populations.

- Fire also offers a valuable window of opportunity for control.
- Understanding the life-cycles of these weeds is an integral part of effective chemical and physical control and preventing spread into intact bushland.

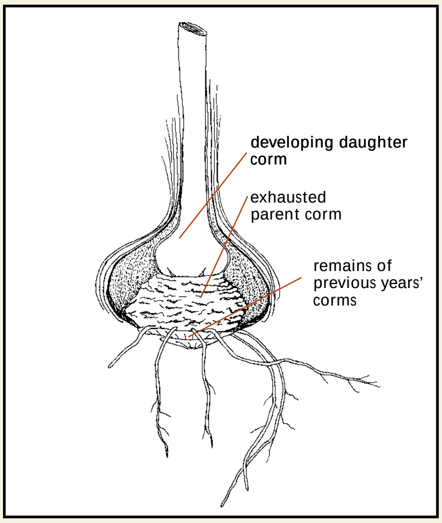
Dealing with weedy geophytes invading bushland can be a complex task. The information in the following case studies illustrates that with a consistent and carefully targeted effort over time, effective control and containment of populations can be achieved. The case studies cover managing and controlling the spread of the Yellow Soldier, two species of *Watsonia*, Harlequin Flower and Taro where they are invading wetlands and woodlands around Perth. The final table provides detailed, species-specific information on control techniques where they are known. The information in the table also highlights the many species of weedy geophytes that have similar life-cycles and reproductive biologies. The next chapter looks at a much more diverse group of weeds, the broadleaf herbs that are not geophytes and the sedges and the succulents.

Box 4.4 Timing herbicide treatment

Annually renewed corms and bulbs

For those species with annually renewed corms and bulbs, the most effective time for herbicide application is when the parent corm or bulb has shrivelled and the new daughter corm/bulb has only partly developed. This usually occurs just before or just at flowering. Apply the herbicide too early and the parent corm/bulb could have enough reserves to survive; too late and the daughter corm/bulb will not be affected.

In addition herbicide application at this time prevents the development of bulbils in many species. This is particularly important with *Oxalis pes-caprae*, *O. glabra* and *O. purpurea* where new bulbils are formed on the nodes of underground stems each year (Du Plessis and Duncan 1989, Peirce 1990, 1998). If herbicide application takes place after bulbils have begun to develop they will probably survive and go on to produce new plants the following season.



Corm exhaustion in Watsonia meriana – late winter.

Perennial corms

Only two species dealt with here arise from perennial corms, Black Flag (*Ferraria crispa*) and Taro (*Colocasia esculenta*). Timing for control of Black Flag is quite problematic as the parent corm does not shrivel and die as the new corm develops, so effectively there is no corm exhaustion. In addition there is a series of previous years' corms below the parent which appear to be joined by a fine thread of living tissue and it is not known if herbicides can be translocated between these corms (Box 4.1)

Effective control of Taro was obtained by cutting and painting the bases in early to mid summer with glyphosate and spraying regrowth in late summer with glyphosate and metsulfuron methyl (Case Study 4.3). Some workers have noted that excessive sap movement when cutting bases early in the season prevents cut stumps from taking up herbicide.

Perennial bulbs

The lowest dry weight of a perennial bulb generally occurs just when all the leaves are up but before flowering (Dafni *et al.*1981). This is probably the time plants would be most vulnerable to herbicide application. An interesting exception is the Easter Lily (*Amaryllis belladonna*) which belongs to a group of bulbs that flower as temperatures drop with the first rains – before the leaves come up. Dry weight in the perennial bulbs with this kind of life-cycle is generally lowest as the new leaves emerge, a couple of months after flowering (Dafni *et al.* 1981) and this is probably the best time to apply herbicide.

Perennial tubers

Herbicide application to Arum Lily is effective throughout its period of active growth (Moore and Hoskins 1997, Brown unpublished data). Early herbicide application prevents the majority of the population flowering and setting seed but misses tubers that begin active growth later in the season.

Studies on Bridal Creeper (*Asparagus asparagoides*) have shown herbicide application to have an impact from flowering through to the green berry stage, although is most effective at flowering (Pritchard 2002).

Case study 4.1 Managing the spread of Yellow Soldier *(Lachenalia reflexa)* in a Banksia woodland

Yellow Soldier (Lachenalia reflexa).

This study investigated the effectiveness of hand-removal and two herbicide treatments on the control of Yellow Soldier (*Lachenalia reflexa*). Trials took place in the species-rich Banksia/Jarrah woodland in Shenton Bushland. The impact of each treatment on the native flora was also recorded.

Carefully hand-removing Yellow Soldier in Shenton Bushland.

Measuring cover of all species in treatment plots

The 'point quadrat' method (Bonham 1989) was used to determine percentage-overlapping cover (referred to as cover) for all species using 200 points within each plot (2 m x 2 m). There were five replicates of each treatment.

Effectiveness of treatments

Hand-removal (1998 & 1999) over two seasons left all natives intact but was very labour intensive, reducing cover of Yellow Soldier by only 44 %. It also triggered germination of annual weeds.

Wiping the leaves (1998) of individual plants with a 10 % glyphosate solution was not effective and was also very labour intensive.

Spot spraying (1999) with metsulfuron methyl at 0.2 g/15 L (5 g/ha) reduced the cover of Yellow Soldier by 65 % in one season and appeared to have no significant impact on native shrubs or herbs including native geophytes.

The control (do nothing) Yellow Soldier increased in cover by over 30 % between 1998 and 2000.

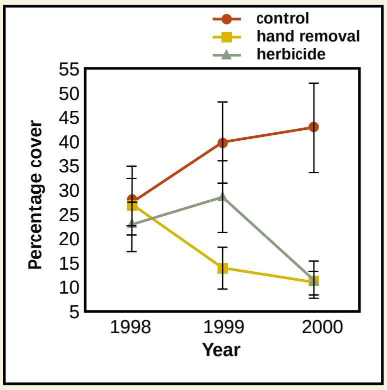


Figure 1. Cover of Yellow Soldier in control, hand-removal and herbicide treatment plots in 1998,1999 and 2000. The bars indicate standard errors.

Impacts on natives

The herbicide treatments did not significantly affect native shrubs or perennial herbs, with both groups increasing in cover in the treatment plots over two years. Although the impacts of the metsulfuron treatment on native geophytes appeared not to be significant it was difficult to assess. There was a large variation across the trial sites in both cover (which is naturally low), and in species. Of the eight species present only one, Milkmaid (*Burchardia congesta*), was present in all 15 plots. Leafy Sundew (*Drosera stolonifera*), Vanilla Lily (*Sowerbaea laxiflora*), Climbing Fringe Lily (*Thysanotus manglesianus*), and *Haemodorum* spp. were present in most plots with Pale Grass Lily (*Caesia micrantha*) and Red Beak Orchid (*Pyrorchis nigricans*) occurring only occasionally.

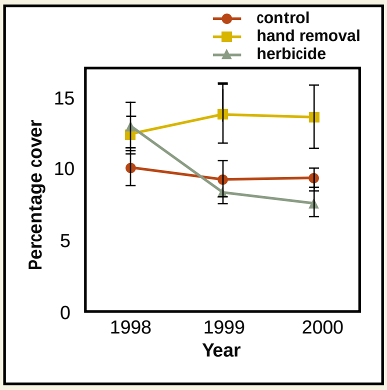


Figure 2. Cover of native geophytes in control, hand-removal and herbicide treatment plots in 1998, 1999 and 2000. The bars indicate standard errors.

Implications for management

Yellow Soldier still comprised 12 % of cover in 2000 therefore indicating that any broad scale application would need to be carefully followed up for a number of years following initial application to ensure re-invasion does not occur.

In the species-rich Banksia woodland at Shenton Bushland, Yellow Soldier co-occurs with up to 25 native species in a 2 m x 2 m plot and the current policy is to allow indigenous species to recolonise treated sites unassisted.

One of the major weeds that invades sites where bulbous weed control has taken place on the sandy soils of the Swan Coastal Plain is Perennial Veldgrass *(Ehrharta calycina)*. A spray program using Fusilade® is successfully controlling this weed over much of Shenton Bushland including the study site.

Stopping the spread

The distribution of Yellow Soldier in Shenton Bushland is not dependent on disturbance, with populations extending into relatively intact bushland (Figure 1, Chapter 2). Preventing spread into undisturbed areas is the primary aim of the control program.

Yellow Soldier spreads within the bushland via seed. The populations are generally quite discrete suggesting seed is not easily dispersed over long distances. Water movement and human activity play a role in the spread. Fire reduces competition from the native vegetation and creates bare areas where the seed can germinate.

Fire, however, can also create opportunities for land managers to prevent further spread and establishment. After fire, Yellow Soldier plants are clearly visible and the reduced cover of native vegetation makes the resprouting flowering bulbs an easy target for herbicide control.

Understanding the current distribution of the weed allows any new infestations to be recognised, recorded and targeted for control.

Note: *In this trial, the metsulfuron methyl was, where possible, targeted at Yellow Soldier and not applied as a blanket treatment over all vegetation. This is not a difficult or time consuming task but does require responsible operators with a reasonable knowledge of the flora. There is evidence from other studies that some native species, particularly seedlings, are susceptible to metsulfuron methyl at 5 g/ha (Moore 1999).*

How the study was used

In the two years since the results of the study became available to the Friends of Shenton Bushland, they have secured funding to implement control of Yellow Soldier across the bushland. The map helped provide information for costing the project and indicated clear objectives to funding bodies. The Friends have since hired an experienced contractor with knowledge of the flora who has carried out the work.

With approximately one hectare of bushland currently invaded the cost of control is relatively low. In the first year funding was obtained through a state government grant and in the second year the local government authority agreed to fund the follow-up work and should continue to do so until the populations require only occasional hand-removal.

Table 1. Costing of Yellow Soldier control over time.

YEAR	TREATMENT	COST/HECTARE	AREA	COST
2001	Brush-off @ 2.5 - 5 g/hectare + pulse@2 mL/L.	$300.00/hectare	~ 1 hectare (from maps)	$300.00
2002	Brush-off @ 2.5 - 5 m/hectare + pulse@2 mL/L.	$300.00/hectare	check 1 hectare	$300.00
2003	As above but also consider hand weeding isolated plants.	$300.00/hectare	check 1 hectare	$300.00?
2004	Now only hand weeding isolated plants may be required.		check 1 hectare	

Source: Brown et al. (2002).

Case study 4.2 Monitoring and managing Watsonia (*Watsonia meriana* and *Watsonia meriana* var. *bulbillifera*) invading wetlands and woodlands across the Swan Coastal Plain

Transect running through Bulbil Watsonia population in Brixton Street Wetlands in a) August 1999 and b) August 2001.

While working on *Watsonia* populations at three different sites across the Swan Coastal Plain, the importance of monitoring the effectiveness of weed management work and of having an understanding of the biology of the target species became apparent. At all sites *W. meriana* and/or *W. meriana* var. *bulbillifera* formed dense monocultures, appearing to displace much of the herbaceous flora and seriously impact on native plant diversity.

Mapping, monitoring and managing the populations

In 1998 the populations of *Watsonia* at Shenton Bushland, Brixton Street Wetlands and Talbot Road Bushland were mapped. Between July and September 1999 a transect was run through the length of each population, from the highly disturbed edge, through the *Watsonia* and into intact bushland. A series of quadrats (1 m x 1 m) were placed at regular intervals along the transects, the number of *Watsonia* in each quadrat counted, all other species occurring in each quadrat recorded and each quadrat photographed. This procedure was repeated in 2000 and again in 2001. Treatments at each site varied as outlined in Table 1.

Shenton Bushland

Introduction and spread The bushland has a long history of having garden rubbish dumped along its boundaries. Alternatively, plant material may have been brought in with laterite gravel in World War II. Spread appears to be by slow expansion of the main population via corms and seed.

Distribution *Watsonia meriana* occurs in a relatively small discrete population in Banksia–Jarrah woodland at the southern end of the bushland.

Response to treatment Two years after treatment a relatively high number of plants remained in the plots (Figure 1) indicating that intensive follow-up will be required for a number of years. Before treatment the *W. meriana* population consisted mostly of large adult plants. One year after treatment the population consisted mostly of small single leafed plants, less than 10 cm high. Those smaller plants arose from corms and were not seedlings.

Table 1. Management actions and herbicide treatment over the monitoring period.

	SHENTON BUSHLAND	BRIXTON ST	TALBOT RD
1999	Green Corps team and Friends wiped entire population with 1:10 glyphosate over 2 days in early September.	Friends and volunteers physically removed plants from the clay flats throughout the season and in early September wiped all plants in the population.	Contractor employed to spray dense infestations on disturbed edge and wipe plants growing closely among natives. (They do not follow instructions and spray glyphosate over native vegetation resulting in loss of some native plants).
2000	Green Corps team again employed to do follow- up wiping. One day's work.	Friends continued hand-removal and in early September Green Corps team assisted wiping the population.	Green Corps employed to do follow-up, wiping individual plants.
2001	Green Corps team employed to do follow-up on the remaining smaller plants. One day.	Plants left now quite numerous but too small for wiping individually and so Friends carry on hand-removal program.	Numbers of plants so reduced that only a few isolated plants left for Friends to deal with.

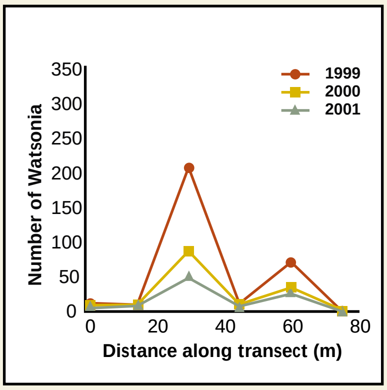


Figure 1. Number of Watsonia meriana *in plots (1 m x 1 m) along a transect through the population in Shenton Bushland in 1999, 2000 and 2001.*

Brixton Street Wetlands

Introduction and spread: There are at least four species of *Watsonia* in the Brixton Street Wetlands; *W. borbonica*, *W. versfeldii*, *W. meriana* and *W. meriana* var. *bulbillifera*. At present only *W. meriana* and *W. meriana* var. *bulbillifera* form dense infestations. Garden refuse, soil movement and work along the adjoining railway line could all have brought in seed and vegetative material. Seed or cormels may also have come in with water movement or birds. Spread appears to be mainly by a slow expansion of populations via corms, cormels and possibly seed. Occasionally however, isolated plants are found 100 metres or more from the main population in undisturbed bushland indicating cormels or seed are dispersed by birds, other animals or human activity.

Distribution: Only a few scattered plants of *W. versfeldii* and *W. borbonica* have been found in the wetlands. The one dense infestation of *W. meriana* that was invading the highly disturbed area of *Viminaria* shrubland has been eradicated by the Friends of Brixton Street. The focus of this study was a dense infestation of *W. meriana* var. *bulbillifera* invading understorey of the Marri woodland.

Response to treatment: The number of *W. meriana* var. *bulbillifera* plants remaining after two years treatment (Figure 2) indicates that intensive follow-up will be required for a number of years in this site also. Once again much smaller plants arising from small corms not seed, made up the population in the years following the initial treatment.

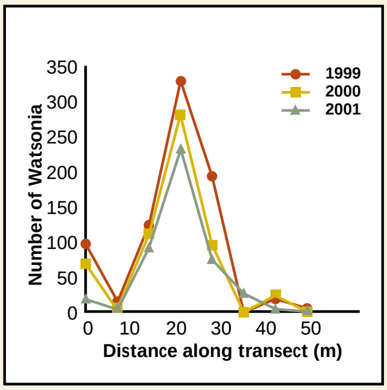


Figure 2. Number of Watsonia meriana *var. bulbillifera in plots (1 m x 1 m) along a transect through the population in Brixton Street Wetlands, 1999, 2000 and 2001.*

Talbot Road Bushland

Introduction and spread: Bulbils or seeds may have come in on maintenance machinery doing works along a drain near the main infestation. Water and soil movement may also have brought material in. Movement into good bushland appears to have been facilitated by soil disturbance associated with track maintenance.

Distribution: A dense infestation of *W. meriana* var. *bulbillifera* occurs in disturbed Marri woodland on the eastern boundary, extending into good bushland for around 40 metres. Occasional isolated plants are found in undisturbed bushland a long way from the main infestation suggesting birds or other animals are playing a role in spread of cormels and perhaps seed.

Response to treatment: The population of *W. meriana* var. *bulbillifera* was effectively controlled in the first year of treatment. No smaller plants came back into the sites and the small amount of follow-up required was on large plants missed the first time around (Figure 3).

What do the results tell us?

Watsonia meriana var. *bulbillifera* responded quite differently to treatment at Talbot Road than at Brixton Street. It appears this is because the population at Talbot Road was initially sprayed with a 1 % solution of glyphosate rather than wiped with 10 % solution, but site differences may also have played a role. Brixton Street is a denser population on a much wetter site. Whatever the cause, intensive follow-up will be required at the Brixton Street site for a number of years. Spraying glyphosate is not an option in bushlands where *Watsonia* grows closely among native flora. The Shenton Bushland population of *W. meriana* is also going to require intensive follow-up for a number of years. Why large numbers of smaller plants continue to come up each year at this site also is difficult to explain – age and density of the population and site conditions may all be playing a role.

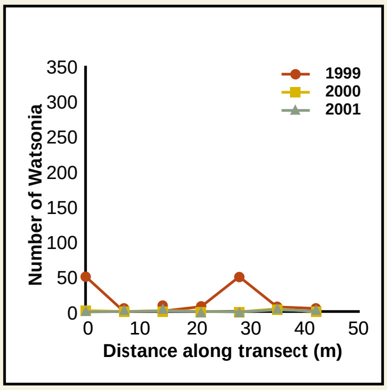


Figure 3. Number of Watsonia meriana *var. bulbillifera in plots (1 m x 1 m) along a transect through the population in Talbot Road Bushland, 1999, 2000 and 2001.*

Understanding the biology of *Watsonia* and monitoring populations is clearly important if this weed is to be effectively managed. This case study highlights the importance of assessing invasive weeds on a site-specific basis and the necessity of resources to be made available over the long term. The results of the monitoring also provided the impetus to look for more effective methods and trials with the herbicide Dalapon (2,2-DPA) in Shenton Bushland are looking promising. This herbicide has been used on roadside populations of *Watsonia* in the Albany region for many years (J. Moore pers. comm.).

Case study 4.3 Control of Taro (*Colocasia esculenta*) and subsequent regeneration of the native plant community – a case study from along the Gingin Brook

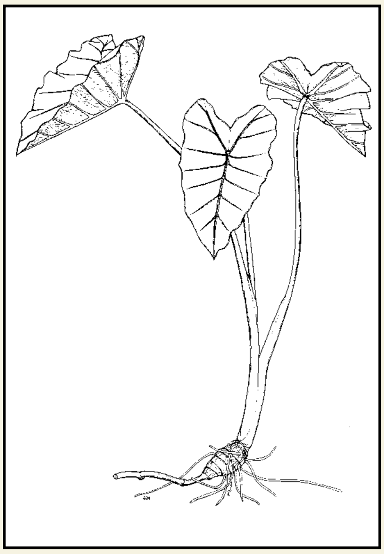


Illustration: IFAS Center for Aquatic Plants 1996.

The study site was located along a section of the Gingin Brook in the town site where Swamp Paperbark (*Melaleuca rhaphiophylla*) and Flooded Gum (*Eucalyptus rudis*) form the main overstorey in the fringing vegetation and Tall Sedge (*Carex appressa*), Tassel Sedge (*Carex fascicularis*) and the fern *Cyclosorus interruptus* the understorey. Where Taro invades it completely displaces the understorey and allows no regeneration of overstorey species.

Physically removing isolated population in summer 1999

Physically removing small (up to 10 m x 10 m) outlying populations, was initially tried in the summer of 1999. The work was quite labour intensive with corms weighing around five kilos and the biomass left to dispose of significant. Follow-up work was required for the next two years and involved removing small plants that was regrowth from pieces left behind. Although effective on smaller populations, physical removal was not practical for larger infestations.

Herbicide treatment in the summer of 2000

In December 2000, following some preliminary trials, all Taro (around one hectare) was cut to the base and the bases painted with a 50 % glyphosate solution. These plants were up to two to three meters high and beyond the reach of a backpack unit. Six weeks later the regrowth, less than one metre high, was carefully spot sprayed with a 2 % glyphosate solution + metsulfuron methyl (0.05 g/L + Pulse® 2 mL/L). A small 750 mL hand held sprayer was used to carefully target Taro regrowth. The glyphosate provided a relatively fast knock-down of top growth so the area covered could easily be seen.

Results from the monitoring transect

Information collected along a transect run from the native vegetation into the Taro infestation showed the treatment was effective (Table 1).

Regeneration of the native plant communities – photo points from the preliminary trials

Preliminary trials over the summer of 1999/2000 provided the basis to treat the entire population of Taro in this way. Fixed photo points at those trial sites showed the treatment was effective. In addition, they showed rapid regeneration of the native plant community. Photo points can provide useful information when the changes are visually dramatic and the plant community relatively simple. In this case the plant community went from almost 100 % cover of Taro to 100 % cover of native species over a couple of years. Only six species of natives made up that cover; Tall Sedge, Tassel Sedge, Swamp Paperbark and Flooded Gum all spread by seed, often in water flow, while *Cyclosorus interruptus* and Native Knotweed (*Persicaria decipiens*) spread rapidly by vegetative means.

Source: Brown and Brooks (in press b).

Small population of Taro, before treatment May 1999.

A bare open patch was left following removal in February 2000.

By May 2001 native sedges, ferns and seedling paperbarks had colonised the open ground.

Table 1. December 2000–before treatment, February 2000–the regrowth, February 2002–one year after regrowth sprayed. Cover values: 1 (<1 %), 2 (1-5 %), 3 (6-25 %), 4 (26-50 %), 5 (51-75 %), 6 (75-100 %) cover.

DATE	NUMBER OF TARO PLANTS IN 10 (1 X 1 M) QUADRATS ALONG A 20 M TRANSECT WITH COVER VALUE IN BRACKETS									
	1	2	3	4	5	6	7	8	9	10
Dec. 2000	0	0	4 (3)	17 (6)	13 (6)	22 (6)	28 (6)	17 (6)	16 (6)	13 (6)
Feb. 2001	0	0	3 (1)	8 (3)	1 (1)	0	6 (4)	10 (5)	14 (6)	10 (6)
Feb. 2002	0	0	0	0	0	5 (1)	0	1 (2)	2 (2)	1 (2)
Distance along transect	1m	3m	5m	7m	9m	11m	13m	15m	17m	19m

Case study 4.4

Protecting threatened plant communities in the Brixton Street Wetlands – an integrated approach.

Work on Harlequin Flower (*Sparaxis bulbifera*) in the Brixton Street Wetlands illustrates that it is possible to prevent the spread of invasive geophytes into relatively undisturbed bushland. The work highlights the importance of:

- Understanding and knowing particular bushland sites.
- Understanding the biology of geophyte weeds.
- Considering a range of control techniques.
- Mapping and recording works programs.
- Monitoring data providing information for management actions.
- Consistency and accuracy in control work.
- Maintaining funding long enough to achieve sustainable results.

Understanding and knowing the site

One of the major threats to the native flora and to the plant communities of the Brixton Street Wetlands is invasion and competition from weeds such as Harlequin Flower. This South African cormous species is a serious invader of clay-based wetlands on the Swan Coastal Plain (Hussey *et al.*1997). Once established it forms dense monocultures displacing herbaceous flora in particular. Given that around 50 % of the native flora at Brixton Street are annual or perennial herbs, many of them rare or restricted taxa (Keighery and Keighery 1995), Harlequin Flower poses a significant threat to the conservation values of this wetland.

Harlequin Flower (Sparaxis bulbifera).

Some observations on the biology of Harlequin Flower

- Although plants produce small cormels up the stems as they die down at the end of each season, populations appear to spread mainly by seed.
- Each plant produces around 75 soft, thin, papery coated seeds, in late spring and within the wetlands at least, water appears to be a major dispersal agent.
- Mapping reveals that populations move mainly through low-lying wet areas along creeks and drains (Figure 1.). Sheet water flow occurring across the wetland in winter may explain small populations occurring in undisturbed bushland.
- Fire facilitates the establishment of new populations in the wetland.
- Harlequin Flower seed appears to be relatively short-lived in the soil. Prolific seedling recruitment was observed throughout the populations of Harlequin Flower before the management program began. One year following removal of all flowering plants from isolated populations, little or no seedling recruitment was observed in those locations.

Timing

Although much of the soil across wetlands is water-logged throughout winter, only in the pools of the heavier clay soils is there standing water. These pools fill with the winter rains. In spring, as the rainfall starts to decrease and the days start to warm up, the water level begins to drop and by November/December they may be completely dry. Flowering and corm exhaustion in Harlequin Flower generally occurs in late September/early October when the pools are low and the soil is drying out.

An integrated approach

Initially it was thought the population could be managed with an intensive hand-weeding program. The first year this was tested it became evident it was going to be extremely labour intensive and expensive. Effective, affordable and appropriate control in the wetlands required a combination of carefully targeted hand-weeding and herbicide application.

From 1999-2002 bush regenerators were employed in the wetlands through September/October to manually remove small isolated populations in undisturbed areas and populations growing around the edges of claypans where herbicide use is inappropriate. At this time of the year the wetland soils are still soft and entire plants including corms come out quickly and easily with minimal soil disturbance.

Workers hand-removing Harlequin Flower in the wetlands

Herbicide trials have indicated that Harlequin Flower can be controlled effectively with metsulfuron methyl (Brush-off®) at 2.5 g/ha (0.1 g/15 L) with limited impact on co-occurring native species in the Brixton Street Wetlands (Brown and Brooks in press c, Table 1). The Harlequin Flower populations are generally fairly discrete and are only ever spot sprayed. A spray contractor with a knowledge of the flora and a background in bushland work has been employed to carry out chemical control on heavier infestations in more disturbed areas and on the drier sites.

To be effective over the three years the project has relied on workers having an understanding of the distribution of Harlequin Flower across the Brixton Street Wetlands. The populations were mapped at the start of the project in 1998.

These maps helped set priorities and allowed for a carefully targeted works program revisiting small isolated populations over a number of years. The maps also enabled us to accurately record works carried out over time and will provide some information on the effectiveness of the management strategy.

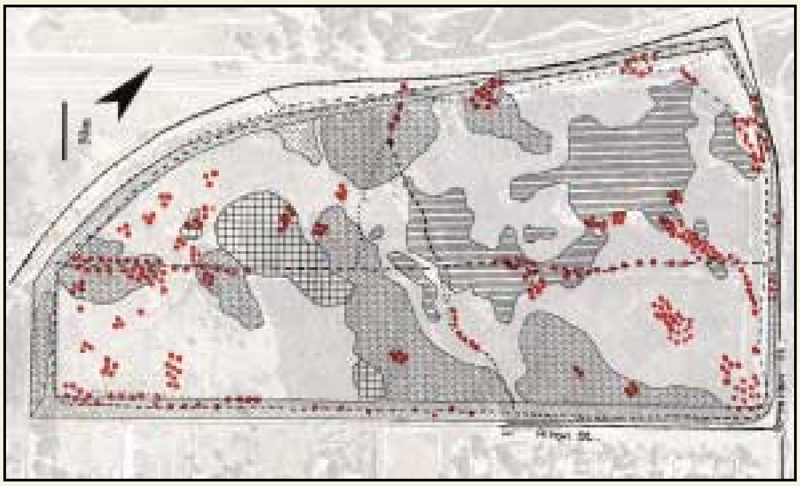


Figure 1. Distribution of Harlequin Flower • across the Brixton Street Wetlands, September 1998.

- Deep claypan (clay) - *Melaleuca lateritia* shrubland, *Amphibromus* grassland
- Wet flats - *Viminaria juncea* tall shrubland/dry flats - mixed low shrublands
- Shallow claypans (wet) - *Pericalymma* open heath
- *Melaleuca* shrubland
- Uplands - Marri Woodlands
- Disturbed areas

Table 1. Native flora co-occurring with Harlequin Flower in the trial plots.

Annual Herbs	***Perennial Herbs-Geophytes***
Aphelia cyperoides	*Burchardia congesta*
Centrolepis aristata	*Burchardia multiflora*
Drosera glanduligera	*Drosera menziesii ssp. menziesii*
Goodenia micrantha	*Philydrella drummondii*
Hydrocotyle alata	*Sowerbaea laxiflora*
Isolepis cernua	*Tribonanthes longipetala*
Schoenus odontocarpus	*Utricularia violacea*
Siloxerus humifusus	***Shrubs***
Perennial Herbs	*Acacia lasiocarpa var. bracteolata*
Borya scirpoidea	*Kunzea micrantha ssp. micrantha*
Chorizandra enodis	*Pimelea imbricata var. major*
Chorizandra multiarticulata	*Verticordia densiflora*
Cyathochaeta avenacea	*Viminaria juncea*
Juncus capitatus	
Lomandra spp	
Meeboldina canus	
Mesomelaena tetragona	

Table 2. Management actions across Harlequin Flower populations in 1998 to 2001.

YEAR	ACTION/TREATMENT
1998	Transects put in place over population. Numbers of Harlequin Flower in each 1 m x 1 m plot counted. No treatment.
1999	Numbers of Harlequin Flower in plots counted again. Population appears to be expanding rapidly. Hand-weeding program attempted across wetlands and all plots hand-weeded.
2000	Plots rescored. Also this year recorded cover estimates (Braun-Blanquet 1965) for all other species, weeds and natives, in plots. Hand-weeding program this year restricted to isolated populations and those in wetter areas. This population (being monitored) sprayed 2.5 g/ha Brush-off ®+ Pulse® 2 mL/L.
2001	Plots rescored and control program continued as for 2000.

More detailed monitoring over time

In September 1998 three 30 metre long transects were run from the disturbed edge of the bushland, through the Harlequin Flower population. Along each transect quadrats (1 m x 1m) were placed at five metre intervals. The aim was to monitor changes in the density of the Harlequin Flower population over time and to gain an understanding of the effectiveness of the management actions.

The populations of mature (Figure 2a) and juvenile Harlequin Flower (Figure 2b) increased from 1998 to 1999 before a management program was in place. Hand-weeding was very effective (1999-2000) and so was the herbicide treatment (2000-2001). The increase in Harlequin Flower one to two metres from the edge over 2000-2001 may indicate that the area missed herbicide treatment. If so it illustrates that there will be reinvasion of populations if follow-up is not consistent in the early years of the control program.

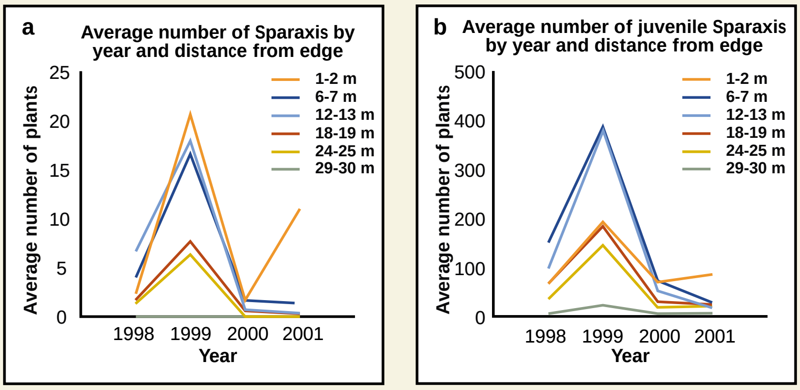


Figure 2. a) Average number of mature (flowering) Harlequin Flower plants and b) juvenile Harlequin Flower plants in plots (1 m x 1 m) along three 30 metre transects over four years (ie three replicates used).

Funding

Funds have to be sought by the Friends of Brixton Street Wetlands each year to continue the work.

It is anticipated that the cost will drop after the first three years. Unless the control program is consistently applied each year in the early stages, reinvasion will probably eventuate.

The work at Brixton Street illustrates that with some resources and a carefully targeted and consistent effort over time, effective control of seriously invasive geophytes like Harlequin Flower moving into undisturbed bushland is possible with minimum off-target damage to co-occurring native species.

Source: Brown and Brooks (in press c)

Table 3. Cost of works, including funding sources, over three years. * A number of volunteers assisted the bush regenerators with their work in the wetlands

TREATMENT	RATE	2000	2001	2002
Physical removal (2 x bush regenerators) *	48 hrs @ $17.50 x 2	$1,680.00	$1,680.00	$1,680.00
Spot spray dense infestations (contractor)	$60.00 per hour	$600.00	$600.00	$300.00
Total		**$2,280.00**	**$2,280.00**	**$1,980.00**
Funding source		*Wildflower Society W.A (Inc.) Perth branch*	*Dept. of Conservation & Land Management*	*Dept. of Conservation & Land Management*

Family	Species	Common name	Storage organ	Reproductive unit	Dispersal agent	Time to first flowering (years)	Flowering	Seedbank persistence (years)
Hyacinthaceae	*Albuca canadensis*		bulb	offsets, **bulbils, seed**		2-3	Sept-Oct	short
Alliaceae	*Allium triquetrum*	Angle Onion, Three-cornered Garlic	bulb	offsets, seed	water, soil	2	Aug-Oct	
Amaryllidaceae	*Amaryllis belladonna*	Belladonna Lily	bulb p	offsets, seed	birds, water, soil	5	Feb-Apr	short
Asparagaceae	*Asparagus asparagoides*	Bridal Creeper	rhiz/tub p	rhiz/tub, **seed**	birds, water, soil	2-3	Aug-Sept	2-3 if buried
Asparagaceae	*Asparagus declinatus*	Bridal Veil	rhiz/tub p	rhiz/tub, **seed**	birds, water, soil	2-3	Apr-Aug	medium?
Asparagaceae	*Asparagus densiflorus*	Asparagus Fern	rhiz/tub p	rhiz/tub, **seed**	birds, water, soil		Mar	medium?
Asparagaceae	*Asparagus scandens*	Climbing Asapargus	rhiz/tub p	rhiz/tub, **seed**	birds, water, soil		Aug-Sep	medium?
Iridaceae	*Babiana angustifolia*	Babiana, Baboon Flower	corm ar	offsets, **seed**	water, soil		Jul-Nov	medium?
Iridaceae	*Babiana nana*		corm ar	offsets, **seed**	water, soil		Aug-Sep	medium?
Iridaceae	*Babiana tubulosa*		corm ar	offsets, **seed**	water, soil		Jul-Aug	medium?
Colchicaceae	*Baeometra uniflora*		corm				Aug-Dec	
Iridaceae	*Chasmanthe floribunda*	African Corn Flag	corm ar	offsets, seed	birds, water, soil	2-3	Jul-Oct	
Araceae	*Colocasia esculenta*	Taro	corm p	offsets, vegetative-fragments	water, soil		Mar-Jul	
Amaryllidaceae	*Crinum moorei*		bulb p			3		short
Iridaceae	*Ferraria crispa*	Black Flag	corm p	corms, seed	soil		Aug-Oct	medium?
Iridaceae	*Freesia alba x leichtlinii*	Freesia	corm ar	offsets, stem-cormels, **seed**	water, soil, birds	2-	Jul-Oct	short?
Iridaceae	*Gladiolus angustus*	Long Tubed Painted Lady	corm ar	offsets, seed?, **cormels**	soil, water		Aug-Nov*	
Iridaceae	*Gladiolus caryophyllaceus*	Pink Gladiolus	corm ar *d*	offsets, **seed**	wind		Aug-Nov	medium?
Iridaceae	*Gladiolus undulatus*	Painted Lady, Wavy Gladiolus	corm ar	offsets, seed, **cormels**	soil, water		Oct-Dec*	medium?
Iridaceae	*Hesperantha falcata*	Hesperantha	corm ar	offsets? **seed**	water, soil		Aug-Oct	medium?
Iridaceae	*Homoglossum watsonium*	Red Afrikaner	corm				Aug-Nov	
Alliaceae	*Ipheion uniflorum*	Spring Starflower	bulb				Sept-Nov	
Iridaceae	*Ixia maculata*	Yellow Ixia	corm ar	cormels on stolons, seed			Aug-Oct	medium?
Iridaceae	*Ixia paniculata*	Tubular Corn Lily, Long Tubed Ixia	corm ar	seed			Sep-Nov	medium?
Iridaceae	*Ixia polystachya*	Variable Ixia	corm ar	variable seed set			Sep-Dec	
Hyacinthaceae	*Lachenalia aloides*	Soldiers	bulb ar	**seed**	water, soil	2-3	Oct	medium?
Hyacinthaceae	*Lachenalia bulbifera*		bulb ar	**bulbils on leaves and stolons,** seed	soil, water	2-3	Sep	medium?bulbils
Hyacinthaceae	*Lachenalia mutabilis*		bulb ar	**seed**	water, soil	2-3	Sep	medium?
Hyacinthaceae	*Lachenalia reflexa*	Yellow Soldier	bulb ar	bulbils on leaves **seed**	water, soil	2-3	Jul-Aug	medium?
Orchidaceae	*Monadenia bracteata*	South African Orchid	tuber p	**seed**	wind		Oct-Nov	6+
Iridaceae	*Moraea flaccida*	One Leaf Cape Tulip	corm ar *d*	offsets **seed**	water, soil	2-3	Sept-Nov	less than 8
Iridaceae	*Moraea fugax*		corm ar	**seed,** cormels		3	Oct-Nov	
Iridaceae	*Moraea lewisiae*		corm ar	offsets, **seed**	soil, water, birds	3	Sept-Oct	

Storage organ: *rhi=rhizome tub=tuber* ***Renewal:*** *ar=annually renewed p=perennial d=some dormancy between fire*
Reproductive units: *bold=main method of dispersal* ***Flowering:*** *period over which plants flower* ***Seedbank persistence:*** *how long seed remains viable short=days to 1yr, medium=1-5yr*

Suggested method of management and control	Timing	References
Spot spray metsulfuron methyl 0.2 g/15 L + glyphosate 1% .		171, 242, 108, 101, 167
Spot spray glyphosate 1 % + Pulse® **or** metsulfuron methyl 0.15 g/10 L + Pulse®.	Just before flowering.	242, 231, 30, 248, 102, 108, 167, 263
Spot spray glyphosate 1 % + Pulse®.	After flowering just as new leaves emerge.	242, 167, 108
Spray glyphosate 1 % + Pulse® **or** metsulfuron methyl 0.04 g/10 L + Pulse®.	Best results when flowering.	242, 167, 270, 264, 346, 222
Spray glyphosate 1 % + Pulse®.	Best results when flowering.	242, 101, 167, 222
Try 1 % glyphosate + 1 g metsulfuron methyl + 25 mL Pulse® in 10 L water.	Best results when flowering.	242, 101, 167, 222
Try 100 mL glyphosate + 1 g metsulfuron methyl + 25 mL Pulse® in 10 L water.	Best results when flowering.	242, 167, 222
Spot spray metsulfuron methyl 0.2 g/15 L + glyphosate 1 % .	Just on flowering at corm exhaustion.	242, 167, 196, 101
Spot spray metsulfuron methyl 0.2 g/15 L + glyphosate 1% .	Just on flowering at corm exhaustion.	242, 167, 196, 101
Spot spray metsulfuron methyl 0.2 g/15 L + glyphosate 1% .	Just on flowering at corm exhaustion.	242, 167, 196, 101, 181
		242, 167
Spot spray glyphosate 1 % + Pulse®.	Before flowering.	242, 167, 108, 222
Cut plants to base, paint metsulfuron methyl 0.05 g/L + glyphosate 50 % . Six weeks later carefully spray regrowth metsufuron methyl 0.05 g/L + glyphosate 1 % + Pulse®.	In summer when actively growing. Some reports suggest later in summer is more effective.	44, 128, 41, 167
		108, 167
Hand-remove very small populations, sift soil to find all corms. Some control spraying metsulfuron methyl 0.2 g/15 L + glyphosate 1 % .	When flowering.	242, 167, 108, 101
Spot spray metsulfuron methyl 0.2 g/15 L + Pulse® (2.5-5 g/ha).	Just on flowering at corm exhaustion.	242, 167, 108, 253
Spot spray metsulfuron methyl 0.2 g/15 L + glyphosate 1 % + Pulse® in degraded sites. Physical removal can result in spread of cormels.	Just on flowering? Once parent corm killed cormels in soil lose dormancy and germinate.	242, 167, 108, 140
Wipe individual leaves glyphosate 10 % , spray dense infesations in degraded area 1 % glyphosate.	Just on flowering at corm exhaustion.	242, 167, 108, 160, 140
Spot spray metsulfuron methyl 0.2 g/15 L + glyphosate 1 % in degraded sites. Physical removal can result in spread of cormels.	Just on flowering? Once parent corm killed cormels in soil lose dormancy and germinate.	181, 242, 108, 140
Spot spray metsulfuron methyl 0.2 g/15 L + Pulse® (2.5-5 g/ha).	Just on flowering at corm exhaustion.	242, 167, 108
		266, 167
Spot spray metsulfuron methyl 0.2 g/15 L + glyphosate 1 %.	Just on flowering at corm exhaustion.	242, 101, 167
Spot spray metsulfuron methyl 0.2 g/15 L + glyphosate 1 %.	Just on flowering at corm exhaustion.	242, 101, 266, 167
Spot spray metsulfuron methyl 0.2 g/15 L + glyphosate 1 %.	Just on flowering at corm exhaustion.	181, 167
Try as for *L. reflexa.*	Just on flowering at bulb exhaustion.	242, 167, 109
Try as for *L. reflexa.* Physical removal can result in spread of bulbils.	Just on flowering at bulb exhaustion.	242, 167, 109
Try as for *L. reflexa.*	Just on flowering at bulb exhaustion.	242, 167, 109
Spot spray metsulfuron methyl 0.2 g/15 L + Pulse® (2.5g-5g/ha).	Just on flowering at bulb exhaustion.	242, 46, 167, 109
Spot spray glyphosate 1 % + Pulse®.	Just on flowering.	30, 242, 101, 167
Spot spray metsulfuron methyl 0.1 g/10 L **or** chorsulfuron 0.2 g/10 L + Pulse®.	Just on flowering at corm exhaustion.	242, 167, 248, 138, 253,
Try as on *M. miniata.*	Just on flowering at corm exhaustion.	108, 167
Try as on *M. miniata.*	Just on flowering at corm exhaustion.	242, 167, 138, 108, 5

Family	Species	Common name	Storage organ	Reproductive unit	Dispersal agent	Time to first flowering (years)	Flowering	Seedbank persistence (years)
Iridaceae	*Moraea miniata*	Two Leaf Cape Tulip	corm ar *d*	offsets, **cormels on stem and base**	water, soil, birds, Cyclone Albey	2-3	Jul-Nov	cormels 8
Iridaceae	*Moraea setifolia*	Thread Iris	corm ar	offsets, **seed**	water, soil	3	Sept-Jan	
Hyacinthaceae	*Muscari comosum*	Grape Hyacinth	bulb	offsets, seed	water, soil, birds		Sep	
Amaryllidaceae	*Narcissus papyraceus*	Paperwhite	bulb p	offsets, seed	soil, water		Aug-Sep	
Alliaceae	*Nothoscordum gracile*	False Onion Weed	bulb	bulbils, seed	soil, water		Oct-Jan	
Hyacinthaceae	*Ornithogalum thyrsoides*	Cincherinchee	bulb	seed	water		Oct-Nov	
Oxalidaceae	*Oxalis depressa*		bulb ar				May-Jun	
Oxalidaceae	*Oxalis flava*	Pink Bulb Soursob	bulb ar	bulbils	soil		May	
Oxalidaceae	*Oxalis glabra*	Finger Leaf Oxalis	bulb ar	bulbils	soil		May-Aug	
Oxalidaceae	*Oxalis incarnata*	Pale-flowered Oxalis	bulb ar	bulbils	soil		Aug-Nov	
Oxalidaceae	*Oxalis pes-caprae*	Soursob	bulb ar	bulbils	soil		Jun-Oct	
Oxalidaceae	*Oxalis purpurea*	Four o'clock, Large-flowered Wood Sorrel	bulb ar	bulbils	soil		May-Sep	
Amaryllidaceae	*Pancratium maritimum*		bulb	offsets, seed			Aug-Oct	
Iridaceae	*Romulea flava*		corm ar	seed		2	Jul-Sep	medium?
Iridaceae	*Romulea obscura*		corm ar	seed		2		medium?
Iridaceae	*Romulea rosea*	Guildford grass	corm ar	seed		2	Aug-Oct	medium?
Iridaceae	*Sparaxis bulbifera*	Harlequin Flower	corm ar	offsets, cormels on stem, **seed**	water, soil	2-3	Sep-Oct	short?
Iridaceae	*Sparaxis pillansii*	Harlequin Flower	corm ar	seed			Sep-Oct	short?
Iridaceae	*Watsonia borbonica*		corm ar *d*	offsets, seed?	wind, water, soil	2-3	Sep-Nov	medium?
Iridaceae	*Watsonia marginata*	Fragrant Bugle Lily	corm ar *d*	offsets, seed	water, soil, wind	2-3	Oct-Dec	medium?
Iridaceae	*Watsonia meriana*	Bugle Watsonia	corm ar *d*	offsets, seed	water, soil, wind	2-3	Sep-Dec	medium?
Iridaceae	*Watsonia meriana* var.*bulbillifera*	Bulbil Watsonia	corm ar *d*	offsets, cormels on stem and base, seed	water, soil, wind	2-3	Sep-Dec	medium?
Iridaceae	*Watsonia versfeldii*		corm ar *d*	offsets, seed	water, soil, wind	2-3	Sep-Nov	medium?
Araceae	*Zantedeschia aethiopica*	Arum Lily	tub/rhiz p	offsets, **seed**	water, birds, soil		Jun-Nov	short

Storage organ: *rhi=rhizome tub=tuber* ***Renewal:*** *ar=annually renewed p=perennial d=some dormancy between fire*
Reproductive units: *bold=main method of dispersal* ***Flowering:*** *period over which plants flower* ***Seedbank persistence:*** *how long seed remains viable short=days to 1yr, medium=1-5yr*

Suggested method of management and control	Timing	References
Spot spray metsulfuron methyl 0.1 g/10 L **or** chorsulfuron 0.2 g/10 L + Pulse®. Physical removal can result in spread of cormels.	Just on flowering at corm exhaustion.	242, 167, 248, 138, 253, 5
Try as on *M. miniata*.	Just on flowering at corm exhaustion.	242, 167, 138, 108
Spray metsulfuron methyl 0.2 g/15 L + glyphosate 1 %.	Just before flowering.	108, 167
Try 1 % glyphosate + 0.1 g metsulfuron methyl + 25 mL Pulse® in 10 L water.	Just on flowering.	101, 167, 222
Try 1 % glyphosate + 0.1 g metsulfuron methyl + 25 mL Pulse® in 10 L water.		222
1 g of metsulfuron methyl in 10 L of water + Pulse® gives partial control.	Before flowering.	300, 228, 167, 222
As for *O. pes-caprae*.	At bulb exhaustion, generally just on flowering.	242, 2, 167
As for *O. pes-caprae*.	At bulb exhaustion, generally just on flowering.	242, 167, 40
As for *O. pes-caprae*.	At bulb exhaustion, generally just on flowering.	242, 167, 40
	At bulb exhaustion, generally just on flowering.	242, 167, 181, 40
Spot spray metsulfuron methyl 0.2 g/15 L + Pulse®, **or** 1 % glyphosate . Physical removal can result in spread of bulbils.	At bulb exhaustion, generally just on flowering.	242, 167, 248, 252, 40
As for *O. pes-caprae*.	At bulb exhaustion, generally just on flowering.	242, 167, 250, 40
		181, 167
Try as for *R. rosea*.	Just on flowering at corm exhaustion.	181, 108, 167
Try as for *R. rosea*.	Just on flowering at corm exhaustion.	181, 108, 167
Spot spray metsulfuron methyl 0.2 g/15 L + Pulse®.	Just on flowering at corm exhaustion.	102, 108, 167
Spot spray metsulfuron methyl 0.1 g/15 L +Pulse® **or** chlorsulfuran 0.3 g/10 L + Pulse®	Just on flowering at corm exhaustion.	242, 167, 45, 222
Try as for *S. bulbifera*.	Just on flowering at corm exhaustion.	242, 167
As for *W. meriana* var. *bulbillifera*.	Just on flowering at corm exhaustion.	242, 194, 108, 167
As for *W. meriana* var. *bulbillifera*.	Just on flowering at corm exhaustion.	242, 139, 108, 167
As for *W. meriana* var. *bulbillifera*.	Just on flowering at corm exhaustion.	242, 139, 108, 167
Wipe individual leaves glyphosate 10 % or spray dense infesations 2,2-DPA 10 g/L + wetting agent or in degraded area 1 % glyphosate.	Just as flower spikes emerge at corm exhaustion.	242, 139, 108, 167
As for *W. meriana* var. *bulbillifera*.	Just as flower spikes emerge at corm exhaustion.	242, 139, 108, 167
Spot spray metsulfuron methyl or chlorsulfuron 0.4 g/15 L of water + Pulse®. Higher concentration in one litre hand held sprayer applying a single squirt to leaves avoids off target damage.	Any time between June and September. Early prevents flowering and seed set but may miss later sprouting tubers.	223, 227, 270, 42, 167

Chapter 5 Broadleaf Herbs, Sedges and Succulents

Herbs are seed plants with non-woody green stems. Grasses and geophytes, both classified as herbs, have been covered in previous chapters. This chapter covers the rest of the weedy herbs. The information is presented in two sections – those broadleaf herbs with an annual life-cycle and then the sedges, succulents and broadleaf herbs with a perennial life-cycle. With their small biomass and ephemeral nature, annuals are often not serious weeds of bushland. Perennial weeds on the other hand, are persistent over time, can form a large biomass and tend to have a much greater impact on native plant communities.

Annual herbs

As a group, annual herbs share similar life-cycles and reproductive biology. They also often share common management and control strategies.

Annual plants complete their full life-cycle from germination to seed production within one year and then die. As their life expectancy is short, they are favoured where frequency of habitat disturbance is high (Hobbs and Atkins 1988, McIntyre *et al.* 1995, Sheppard 2000). They are among the most commonly occurring weeds on the disturbed edges of bushland. Soil disturbance and nutrient run-off in particular, facilitate the rapid establishment of weeds with an annual life-cycle.

In south west Western Australia, most annual weeds germinate with the first autumn rains, grow actively over the winter spring period and set seed and die with the onset of higher temperatures in summer. In wetlands though, some annual weeds germinate as water levels drop in spring, grow actively over the summer months setting seed in autumn. Examples of the latter include Bushy Starwort (*Symphyotrichum subulatum*) and Prickly Lettuce (*Lactuca serriola*). Others can germinate and go through to flowering whenever conditions are suitable, often several times over the one year. Caltrop (*Tribulus terrestris*) and Doublegee (*Emex australis*) are good examples.

Impacts

Although there are large numbers of introduced annual herbs there are only a few species that are serious weeds of bushland in south west Western Australia. Many co-exist among native plant communities without having much of an impact and are often not a high priority for management. However, it is important to consider the impacts of particular annual weeds at individual sites and over several seasons. There are a number that can be serious weeds in particular plant communities and under certain seasonal conditions.

For example, Lupins (*Lupinus angustifolius, Lupinus consentinii*) are one of the more serious annual weeds in Banksia woodland around Perth. They can form dense stands that prevent regeneration of native plants and alter the soil chemistry through nitrogen fixation (Swarbrick and Skarratt 1994). Each year Fumitory (*Fumaria capreolata*) grows up and smothers native shrubs and seedlings among the understorey of Banksia woodlands. The seed remains viable in the soil for several years (Chancellor 1996, Peltzer and Matson 2002) germinating with the onset of any disturbance. *Isolepis hystrix* is emerging as a serious annual weed of clay-based wetlands where it forms dense mats, competing with the rich native annual flora (Keighery 1999c).

Annual weeds can have a serious impact where they invade native herbfields on granite outcrops (Hopper *et al.* 1996, Pigott and Sage 1996) and the herbaceous understorey of York Gum (*Eucalyptus loxophleba*) – Jam (*Acacia acuminata*) woodlands. They are also often prolific on the highly degraded edges of bushland. Restoring these sites often involves dealing with continual germination of annual weeds competing with regenerating natives.

Management and control

Management and control of this group of weeds is about preventing germination and seed set. On highly degraded edges it may sometimes involve restoring/re-establishing the cover of some local species that will displace and out-compete annual weeds and prevent further dispersal of weed seed into undisturbed areas.

Preventing establishment

Minimising soil disturbance

Persistence of annual weeds at a site is often due to a long-lived soil seedbank that will germinate with the onset of any disturbance. Often the soil disturbance brought about by removal of perennial weeds is enough to stimulate germination of annual weed seed that has lain dormant in the soil. As soon as space and light become available dormancy is broken, seeds germinate and seedlings establish (Box 5.1).

Box 5.1 Black Nightshade – a disturbance opportunist

An isolated clump of Arum Lily removed from among native sedges and ferns along the Gingin Brook was very quickly replaced by a dense monoculture of the annual Black Nightshade (*Solanum nigrum*). Seed of Black Nightshade can remain viable in the soil for up to eight years and dormancy can be broken by light (Thullen and Keeley 1982). Black Nightshade will need to be controlled until the soil seedbank is exhausted or native perennials fill the gap and prevent further germination.

A patch of Black Nightshade coming up where an isolated clump of Arum Lily has been physically removed.

Illustration provided by: IFAS, Centre for Aquatic Plants University of Florida, Gainesville, 1996

Other annual weeds establish by rapidly dispersing into recently disturbed sites. Many annual weeds of the Swan Coastal Plain and Jarrah Forest belong to the daisy family (Asteraceae), a group with largely wind dispersed seed. They are able to disperse effectively into sites of soil disturbance, rapidly growing and exploiting available resources (McIntyre *et al.* 1995). Often the most prolific is the wind dispersed Flat Weed (*Hypochaeris glabra*) (Box 5.2).

Box 5.2 Fire and soil disturbance in a Banksia woodland

The disturbance caused by fire and then the hand-removal of Yellow Soldier (*Lachenalia reflexa*), an introduced bulb, in study plots in Shenton Bushland encouraged the establishment of weedy annuals.

Fire

The initial increase in cover of annual broadleaf weeds that occurred over 1998/1999 across all plots was probably a reflection of conditions following the October 1997 fire. The gaps created by the fire and the increased nutrient levels provide ideal conditions for annual weed establishment.

Soil disturbance

Where Yellow Soldier was removed by hand and the soil disturbed, the cover of annual weeds increased to an even greater degree. Flat Weed (*Hypochaeris glabra*) was the most prolific. With its wind dispersed seed and flat rosette of leaves it is a prime example of a weed able to disperse effectively and rapidly exploit available resources. Other broadleaf annual weeds colonising the plots included Ursinia (*Ursinia anthemoides*), French Catchfly (*Silene gallica*), and Slender Suckling Clover (*Trifolium dubium*). Any hand-removal program aimed at controlling bulbous weeds such as Yellow Soldier in Banksia woodland is likely to result in colonisation by annual weeds.

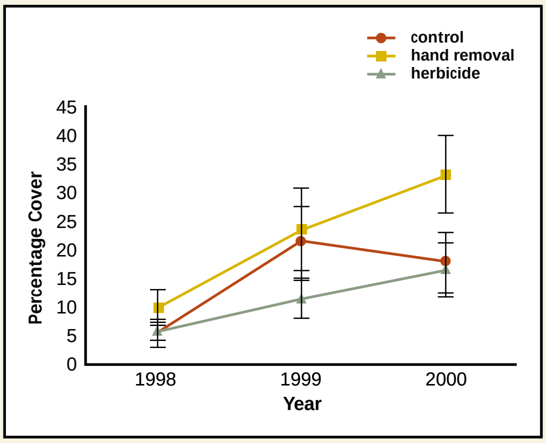


Figure 1. The cover of weedy annual herbs in plots (2 m x 2 m) for three years following fire. Bars indicate standard errors.

Keeping out fire

Fire can also facilitate invasion of annual weeds into bushland. Weed seed builds up in the soil seedbank between fires. After fire many annual weed species germinate, exploit available resources and set seed before native species (Fisher 1998, Perez-Fernandez *et al.* 2002). In the two years following fire at Shenton Bushland, the cover of annual weeds at study sites increased greatly (Box 5.2).

Assisting regeneration of the native plant community

Management that favours the regeneration of native plant communities increases competition against weeds. Annual weeds, probably more than any other weeds, can be displaced and prevented from establishing through careful bush regeneration - encouraging regeneration of the native plant communities and allowing native plants to fill gaps (Bradley 1988, Vranjic *et al.* 2000). This can be a particularly useful tool when fast-growing native perennials are present (Box 5.3).

Stimulating the native soil seedbank to germinate by the use of smoke or smoke-derived products (Dixon *et al.* 1995, Roche *et al.* 1998) is one way to encourage regeneration of the native plant community. At most disturbed sites weed management will be labour intensive and ongoing until a cover of native species is well established.

Direct seeding with local provenance seed

If there is no native soil seedbank remaining, as in many degraded sites on the edge of bushland (Fisher 1998), then direct seeding the site is the next option.

Consider the following:

- The great diversity of native flora of south west Western Australia is recognised internationally. Less well known is the diversity we cannot see, hidden diversity in the genetic make up of our flora (Byrne 2002). In order to protect the integrity of that genetic diversity, always collect seed locally, i.e. from bushland adjoining the restoration site. Collecting seed for restoration work locally is, at present, the only way to avoid introducing non-local genetic material and non-local forms of plants to bushland. It also ensures plants established are adapted to local conditions (Box 5.4).
- Ensure that the species selected occur on the soils and are from the plant community of the site that is being restored. Vegetation maps, species lists and near-by intact bushland are useful reference points.
- Think about species selection. When the aim of the project is to displace annual weeds along a disturbed edge, think about selecting easy to establish, fast-growing species. Remember though, returning as much of the natural diversity to the site as possible is the long-term objective.
- Weed control will be ongoing for many years until a cover of native plants is well established.

- Success will often depend on at least one or two year's site preparation and seed collection and a long-term access to resources for follow-up work.
- Results will vary across sites, soils, seasons, plant communities and species selected.
- Ensure appropriate permits have been acquired before seed collection is undertaken.

Control methods

There are 60 species of annual weeds listed in the table at the end of the chapter. Methods of control are often going to be quite specific for each species. Nevertheless, some useful generalisations can be made.

Physical control

- Hand-removal is only useful before seed set and all flowering material should be taken from a site. Left behind, it may well go on to produce seed.
- Mowing or brushcutting can reduce seed production and reduce populations if carried out well before seed set. As slashing is non-specific it is really only useful in highly degraded sites. Work needs to be

Box 5.3 Managing annual weeds after Arum Lily control – experience from the banks of Bennett Brook

Trials on different methods to control Arum Lily along Bennett Brook highlight the invasive potential of annual weeds. The trials were located in a very degraded patch of Flooded Gum (*Eucalyptus rudis*) – Swamp Paperbark (*Melaleuca rhaphiophylla*) woodland. The understorey in most places was a monoculture of Arum Lily. Weeds that moved into areas where Arum Lily had been controlled included 12 species of annual weeds (nine broadleaf herbs and three species of annual grasses) (Table 1.).

Interestingly, the only natives to move into the site were four species of herbaceous perennials, all of them fast-growing, easily-propagated, mat-forming plants highly suitable for displacing weeds, particularly those with an annual life-cycle. Such species are often present in disturbed wetland sites and they provide a great opportunity to quickly fill gaps, helping prevent further germination of annual weeds.

Slender Knot Weed (Persicaria decipiens).

Water Buttons (Cotula coronopifolia).

Table 1. Weeds and natives that colonised the site following removal of Arum Lily.

WEEDS	
Annual Grasses	
Annual Rye Grass	*Lolium* sp.
Annual Veldgrass	*Ehrharta longiflora*
Annual Barb Grass	*Polypogon monspeliensis*
Perennial Grasses	
Phalaris	*Phalaris aquatica*
Annual Herbs	
Bushy Starwort (annual or biennial)	*Symphyotrichum subulatum*
Pimpernel	*Anagallis arvensis*
Common Starwort	*Callitriche stagnalis*
Pattersons Curse	*Echium plantagineum*
Lesser Loosestrife	*Lythrum hyssopifolium*
Slender Birds Foot Trefoil	*Lotus angustissimus*
Plantain (or short-lived perennial)	*Plantago major*
Sow Thistle	*Sonchus oleraceus*
Sharp Buttercup	*Ranunculus muricatus*
Perennial Herbs	
Clustered Dock	*Rumex conglomeratus*
Water Cress	*Rorippa nasturtium-aquaticum*
	Juncus microcephalus
NATIVES	
Perennial Herbs	
Water Buttons	*Cotula coronopifolia*
Centella	*Centella asiatica*
Joy Weed	*Alternanthera nodiflora*
Slender Knot Weed	*Persicaria decipiens*

carefully timed; too early and some species will resprout. Slash too late (after seed set) and the result will be further spread of propagules and expanding populations of the weed the following year.

Chemical control

Spot spraying with glyphosate generally **well before flowering** is the recommended herbicide control for many annual weeds. There are some species of annual weeds not killed by glyphosate. Check the table at the end of the chapter.

Box 5.4 Using local provenance seed in restoration (from Keighery *et al.* 1998)

This is a list of species from Brixton Street Wetlands that can be easily propagated for restoration purposes. The list highlights the importance of using locally collected seed. Many species have locally occurring forms that could be lost with the introduction of genetic material (seeds or cuttings) from other areas.

FAMILY/SPECIES	HABITAT	PROPAGATION
Anthericaceae		
Sowerbaea laxiflora	dry	division/seed
Tricoryne humilis	dry	division/seed
Asteraceae		
Hyalosperma cotula	dry/damp/wet	seed
# *Podolepis gracilis*	damp/wet	seed
Haemodoraceae		
Anigozanthos manglesii	dry	seed
Mimosaceae		
# *Acacia lasiocarpa*	dry/damp	seed
# *Acacia pulchella*	dry	seed
# *Acacia saligna*	dry	seed
Myrtaceae		
# *Astartea* aff. *fascicularis*	wet	seed
Baeckea camphorosmae	dry/damp	seed
Eucalyptus calophylla	dry	seed
Hypocalymma angustifolium	dry/damp	cuttings/seed
Hypocalymma robustum	dry	cuttings/seed
# *Melaleuca rhaphiophylla*	wet	seed
# *Melaleuca viminea*	wet	seed
Pericalymma ellipticum	damp/wet	seed
Papilionaceae		
Kennedia prostrata	dry/damp	seed
Viminaria juncea	damp/wet	seed
Proteaceae		
# *Grevillea bipinnatifida*	dry/damp	cuttings/seed
# *Hakea trifurcata*	dry/damp	seed
# *Hakea prostrata*	dry/damp	seed
# *Hakea varia*	damp/wet	seed

Key # Species with recognised local variants Habitats dry = uplands damp = waterlogged areas wet = inundated areas.

As glyphosate is non-specific it needs to be carefully targeted and is only useful in degraded sites where there is no danger of off-target damage.

In direct seeding trials, the Main Roads Department has found that Lontrel at 500 mL/ha controls Lupins and Cape Weed in the early stages with little off-target damage to native species (Grist and Thompson 1997). Clopyralid, the active ingredient of Lontrel, is particularly effective on members of the Asteraceae (daisy family) and the Fabaceae (pea family).

Important note: *Lontrel can persist in the soil for several months, is not bound by soil particles, and is highly soluble. It should only be applied in bushland by well-qualified, responsible operators with a thorough knowledge of the native flora* (see Chapter 8.).

Key points

- The majority of annual weeds do not have serious impacts in bushland and are often not a priority for management.
- Annual weeds often germinate from soil stored seed or disperse into a site following removal of more serious perennial weeds.
- Their management is then the next step in the restoration process – sometimes simply waiting for native perennials to fill the gap.
- Preventing the establishment of annual herbs in bushland is about minimising soil disturbance, nutrient run-off and fires.
- Limiting spread is about preventing or reducing seed set.
- Restoration of native plant communities along the disturbed edges, either through germination of the native seedbank stored in the soil or direct seeding, is often part of a long-term solution to management of annual weeds.

Perennial herbs

Perennial plants have a life span that extends over two or more years. The perennial herbs covered in the table at the end of this chapter are a diverse group. They include everything from succulents and sedges to plants with underground storage organs, to Pelargonium and perennial members of the daisy (Asteraceae) family. They have a diverse range of life-cycles and mechanisms for spreading into bushland. As management and control strategies vary accordingly, it is not possible or useful to provide general information for the group as a whole.

Instead, case studies are presented for three weedy perennial herbs of the Swan Coastal Plain and Jarrah Forest. They illustrate how some of the weeds in this group can be managed where they are invading bushland. Detailed control techniques and information on the biology for specific species that are serious weeds in the region are provided in the final table.

Case study 5.1 Direct seeding to manage annual weeds along a disturbed edge of Swish Bush (*Viminaria juncea*) shrublands

Site history

- The site has a long history of soil disturbance associated with track and drain maintenance.
- **Before 1995:** The site was 100 % covered by *Watsonia meriana* with a few emergent Swish Bushes. The *Watsonia* population provided a continual source of propagules to the adjoining intact bushland.
- **1996 and 1997:** The Friends of Brixton Street sprayed the *Watsonia* (1 % solution of glyphosate as flower spikes were emerging) for two consecutive years eradicating the population.
- **1998 and 1999:** Invasion by a large number of annual and a few perennial weeds followed. Early in the season Wild Radish (*Raphanus raphanistrum*), Wild Oat (*Avena barbata*) and Annual Veldgrass (*Ehrharta longiflora)* were prolific and later on Slender Suckling Clover (*Trifolium dubium*), Patersons Curse (*Echium plantagineum*), Lotus (*Lotus angustissimus*), Vicia (*Vicia sativa*) and Stagger Weed (*Stachys arvensis*) covered the site.
- There was also some recruitment of native species, mostly isolated seedlings of shrubs including Swish Bush, Running Postman (*Kennedia prostrata*), and *Acacia lasiocarpa* var. *bracteolata*. The adjoining bushland is rich in native herbs and some of these also moved into the site, tending to colonise bare soil – Yellow Autumn Lily (*Tricoryne elatior*), *Centrolepis aristata* and *Goodenia micrantha* were the most common.
- Given the resources available, hand-weeding was not an option. Spot spraying of 1 % glyphosate was required four times over the season as germination of soil stored weed seed continued.

The Swish Bush shrublands at Brixton Street occur on winter-wet clay soils.

- The management of this site in the longer term required restoration of native plant cover, particularly fast-growing perennials to displace, shade out and prevent continual germination of weedy annuals over the winter and spring seasons.
- Trials with smoke water at the site in autumn 1999, indicated little viable native seed remained in the soil.

The trial

Seed collection and species selection

Seed was collected from adjoining Swishbush shrublands over the summer. Species selected included five shrubs: *Acacia lasiocarpa* var. *bracteolata*, Swishbush, *Hakea trifurcata*, Running Postman and *Verticordia densiflora*. Seed was also collected from Foxtail Mulga Grass (*Neurachne alopecuroidea*) and Clustered Lovegrass (*Eragrostis elongatus*), chosen for their potential to occupy bare ground quickly. There was one disadvantage in using grasses; grass-selective herbicides could not be used in follow-up weed control as germinating native grass seedlings are susceptible.

Site preparation and trials

- The site was spot sprayed with 1 % glyphosate twice over the autumn prior to setting up the direct seeding trial.
- Prior to sowing, the soil surface in trial plots was very lightly raked to create microsites for seed germination and to prevent the seed blowing away.
- Trial plots measured 2 m x 2 m and there were three replicates of two different seed mixes (shrubs only and shrubs and grasses) and a control – no seed.
- The hard-seeded legumes (*Acacia*, *Kennedia* and *Viminaria*) were all soaked in just-boiled water for two hours prior to sowing.
- Once seed was broadcast, plots were sprayed with Regen 2000 (smoke water) diluted to 100 mL/L (Lloyd *et al*. 2000). The aim was to break dormancy and stimulate germination of the *Verticordia* and the native grass seed.
- Heavy rains fell in the days following sowing.

July 2000 just after direct seeding.

July 2002, two years later.

***Note:* 1.** *Disturbing the soil to create a seed bed for germination can easily facilitate establishment of more weeds.*
2. *Viability of seed was not determined before sowing but subsamples were set aside for the purpose should germination failure occur.*

The trials were hand-weeded twice and sprayed with grass-selective herbicide where appropriate in the winter season following sowing (2000). No weed control took place in 2001.

Establishment of natives

Two years after sowing, in June 2002, all seeded plots had 100 % cover of natives. *Hakea trifurcata* formed the greatest cover in all plots followed by *Acacia lasiocarpa*, Swish Bush, Running Postman then *Verticordia densiflora*. Foxtail Mulga Grass occurred at 25-50 % cover in two plots and 1-5 % in the third. Clustered Lovegrass had not germinated in any plots. All the controls (not seeded) had less than 1 % cover of native species.

Effectiveness in displacing annual weeds

The same 6 -10 species of annual weeds occurred across all plots, seeded and not seeded. The most commonly occurring were Scarlet Pimpernel, Wild Oat, Blowfly Grass, Slender Suckling Clover, Slender Birds Foot Trefoil and Silver Grass (*Vulpia* species). Together they formed 100% cover in all the control (unseeded) plots. In the seeded plots, where native cover was established, the weeds were more scattered and less vigorous with reduced flowering and seed production.

Management implications

- Although a cover of native species was established within two years at this site, the complete displacement of annual weeds is a longer-term project.
- Direct seeding will need to be at a larger scale than the trial plots (2 m x 2 m).
- Weed control in the winter season following sowing will need to be very intensive to ensure seedling establishment.
- Establishment of native shrub cover along the disturbed edges will begin to reverse the cycle of degradation. It will prevent further weed encroachment into intact bushland and, over time, reduce resources required for weed control.

This case study highlights the complexities of restoring degraded bushland edges where there are scattered regenerating natives among a diverse weed flora.

Case study 5.2 Preventing further spread of a recent invader – Holly-leafed Senecio (*Senecio glastifolius*)

Holly-leafed Senecio, a tall perennial herb from the daisy family, occurs naturally in the Cape Region of South Africa. It was first recorded as naturalised in Western Australia in 1986 (Western Australian Herbarium 1998). Collected from the Mt Adelaide and Mt Clarence Nature Reserves in the south west town of Albany, Holly-leafed Senecio was apparently an escapee from a garden adjoining the reserve. A series of fires facilitated rapid expansion of the original infestation and slashing of fire breaks contributed to further spread of seed. Holly-leafed Senecio now occurs throughout much of the 260 hectares of Jarrah (*Eucalyptus marginata*), Albany Blackbutt (*Eucalyptus staeri*), and Marri (*Eucalyptus calophylla*) woodlands, as well as *Allocasuarina* open woodland, in the reserves. In recent years infestations have also been found growing on coastal sands and loams up to 20 kilometres from the original infestation (Western Australian Herbarium 1998). Holly-leafed Senecio has the potential to become a major weed of natural areas around much of the south coast of Western Australia (Keighery 1999c).

Senecio glastifolius (photograph Greg Keighery)

Why is it such a successful weed?

- Produces prolific amounts of viable, wind dispersed seed.
- Some evidence of persistent soil seedbank.
- Fire is a major mechanism for establishment and facilitates spread.
- Soil disturbance also facilitates spread and establishment.

(from Williams *et al.* 1999)

Management

The Mt Adelaide and Mt Clarence Nature Reserves are vested in the City of Albany. Until very recently few resources have been available for weed management in the Reserves. Although the original infestation of Holly-leafed Senecio threatened natural areas from Augusta to Albany and possibly beyond, it was never clear who was responsible for its eradication. Community volunteers initiated the first control programs.

The following report comes from Karin Baker, Friends of Mt Adelaide and Mt Clarence Nature Reserves

- **1998:** Fire followed by good rains led to prolific germination of Holly-leafed Senecio on the north face of the saddle between Mt Adelaide and Mt Clarence. Many people who used the reserves for their daily walks started hand-pulling the plants and leaving them in the Reserves. (It was not known at this stage that they could form seeds after being pulled). Three community volunteers started a hand-removal program in a Casuarina open woodland area, where the thickest infestations occurred.
- **1999:** Holly-leafed Senecio was hand-removed from dense thickets of *Acacia pulchella* up to 700 mm high. Hand-pulling in this area required thick gloves and trousers. Some of the Holly-leafed Senecio removed was two and a half metres tall. This time the plants were removed from the site. We were learning!
- John Moore and Dale Baker, a board member of the first CRC (Cooperative Research Centre) for Weed Management Systems ran a series of herbicide trials. Lontrel at 500 mL/ha applied from a backpack mister in spring was found to be effective on the Holly-leafed Senecio and caused little damage to the native species in the area.
- The CRC for Weeds and the Department of Agriculture, Western Australia held the state launch of ‘Weedbuster Week’ at the Mt Adelaide and Mt Clarence Reserves in October. Over 100 people turned up to hand-pull Holly-leafed Senecio and the ‘Friends of Mt Adelaide & Mt Clarence Reserves’ was formed. The following year the Bushcarers Group, an umbrella group for all the Friends groups that were starting up around the city was formed.
- Following on from the work day, populations were sprayed with Lontrel (500 mL/ha).

- Further spot fires in the following years have produced a germination of Holly-leafed Senecio. These have been dealt with as quickly as time and labour allow. Green Corps teams have been used but are not usually available at the time they are most needed.
- **Outcome:** Areas where there is a good cover of natural vegetation have had very little Holly-leafed Senecio growing in the following years. However, along slashed firebreaks and under power lines, germination occurs every year. Outbreaks should be sprayed or hand - pulled in the first year following fire, to stop the spread of seed.
- Being wind dispersed, there is probably seed all over the reserves, and any fire will result in further outbreaks.

As well as 260 hectares of the nature reserves to deal with, outlying populations also needed to be covered as a priority and resources were limited.

In 2000, Holly-leafed Senecio was placed on the 'Alert List for Environmental Weeds' – weeds identified by Environment Australia as likely to be a significant threat to biodiversity. Grants to undertake on-ground actions to manage/control isolated populations of weeds listed became available. The objective was to prevent further establishment and expansion of listed weeds.

The Department of Agriculture, Western Australia, City of Albany and Albany Bushcarers jointly applied for funding to have the current distribution of the Holly-leafed Senecio mapped and to implement a carefully targeted control program. They were successful and work will begin in spring 2002.

The case study is an example of community, federal, state and local government working together to acquire resources and to implement effective on-ground management of weeds invading natural areas. With any one of the parties not present, the work would not be possible. It also highlights, again, the importance of early intervention and eradication of small infestations of new weeds.

Source: Information for the case study was provided by Karin Baker, (Friend of Mt Adelaide & Mt Clarence Reserves), Greg Keighery (DCLM), John Moore (Western Australian Department of Agriculture, Albany) and Ryan Munro (City of Albany).

Case study 5.3

Geraldton Carnation Weed (*Euphorbia terracina*) – managing the spread of a serious invader

Geraldton Carnation Weed has been slowly spreading south and east over the last 60 years and habitats at risk include bushlands of the offshore islands and calcareous (limestone) plant communities throughout southern Western Australia (Keighery and Keighery 2000).

Reproductive biology, dispersal and spread

- Short-lived perennial herb to one metre.
- Loses leaves and dies back to a stem in summer, reshooting with the first autumn rains.
- Often but not always killed by fire.
- Regenerates from soil-stored seed. Seed remains viable in the soil for at least 3-5 years. Bulk of seed germinates with onset of autumn rains but will germinate after good summer rains.
- Seed released explosively from fruits.
- Water, soil movement, birds (particularly feral doves), and possibly ants play a role in dispersal. Often introduced into bushland with crushed limestone material brought in for paths.
- Is increasing on roadsides and highways. Soil movement and road maintenance machinery are one of the major mechanisms for long distance dispersal.

(Source: Keighery and Keighery 2000, Randall and Brooks 2000, Parsons and Cuthbertson 2001).

Impacts

In Western Australia Geraldton Carnation Weed can be found invading natural ecosystems from Geraldton to Cape Arid. It has been recorded in coastal dune heath, limestone heath, Tuart woodland, Banksia woodland and ephemeral wetlands. Once established it is able to invade relatively undisturbed bushland. It is a particularly serious weed of Tuart woodlands and one of the few serious weeds of coastal heath in south west Western Australia (Keighery and Keighery 2000).

Control and Management in Kings Park

Geraldton Carnation Weed is invading Kings Park Banksia woodlands in four main locations. Management has effectively focused on preventing spread through the identification and eradication of new outbreaks.

- Volunteers and contractors are able to accurately identify the weed and new outbreaks are mapped as soon as located.
- Large infestations are initially spot sprayed with herbicide Brush-off® (1 g/150 L) or Brush-off® + glyphosate. Follow-up includes regular inspection of the site and hand-removal of remaining plants. This continues for at least five years.

Note: *The entire plant must be removed. Plants as young as three weeks will resprout from any root material left behind.*

Euphorbia terracina *invading the understorey of Tuart woodland at Bold Park.*

The program has resulted in a significant reduction of Geraldton Carnation Weed invading the bushland in Kings Park.

Effective management has relied on:

- Recognising, recording and removing new infestations.
- Revisiting known populations year after year (for at least five years) following up previous work.

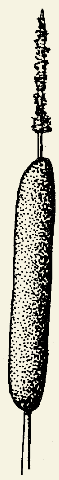
(From Dixon 2000)

Cautionary note: *The sap in the stems of* Euphorbia terracina *is highly caustic and can cause quite dramatic and painful inflammations of sensitive skin. If the sap gets into the eyes temporary blindness is often reported and in some severe cases varying vision loss has been reported. When working with this plant, or any Euphorbia, care should be taken to minimise direct contact with the plant. Safety glasses or face shields and gloves, at a minimum, with fully enclosed shoes and neck to wrist to ankle protection is advised.*

Case study 5.4 *Typha orientalis* – an aggressive coloniser of wetlands

Two species of Typha are known from Western Australia, *T. domingensis* and *T. orientalis*. Native to eastern Australia, *T. orientalis* is thought to be introduced in Western Australia and it is an aggressive coloniser of wetlands of the Swan Coastal Plain and Jarrah Forest. *Typha domingensis* is native and occurs only occasionally in the region. The native and the weed can be difficult to tell apart.

Typha domingensis has a leaf blade that does not exceed 8 mm in width and a cinnamon brown female flower spike that is 5 to 20 mm in diameter and 6 to 20 times as long as it is wide.



Typha orientalis has a leaf blade up to 14 mm wide with a chestnut brown female flower that is 10 to 30 mm in diameter and 5 to 10 times as long as it is wide. Intermediates exist and expert help is sometimes required for identification.

Life-cycle and Reproductive Biology of Typha orientalis

- Expansion of existing populations is rapid, occurring via rhizomes that grow out from the population each season. Establishment of new populations is via seed.
- *Typha orientalis* can produce 220,000 seed per flower head. The seed is very light and wind-dispersed, often over several kilometres. Seed also spreads via water and is moved around in mud on the feet of birds, livestock and humans.
- Seed germination generally takes place from December to April.
- High temperatures (above 20° C) and high levels of light are required for germination. Seeds germinate in mud on the margins of waterways and, sometimes, under water (less than eight centimetres deep).
- Once established, seedlings start producing rhizomes and the diameter of the plant can extend to three metres within the first year.
- Active growth is mainly through summer and autumn although in mild climates it can occur at any time of the year.
- Flowering commences in early summer and seed is dispersed from December onwards.

(from Parsons and Cuthbertson 2001)

Establishment and spread of Typha orientalis at Lake Forrestdale

A study based on a series of aerial photographs of Lake Forrestdale just south of Perth illustrates how quickly the weed can spread once established at a site (Watkins and McNee 1985). The aerial photos revealed that prior to 1964 no *T. orientalis* occurred at the lake, with the first stand appearing in 1967. By 1976 a fairly large stand had established on the southern end of the lake and by 1984 *T. orientalis* had colonised almost the entire six kilometres of lake margin. Dense colonies had in many places displaced the native rushes and sedges in the understorey of the *Melaleuca* woodland fringing the lake. Seed had been responsible for the establishment of new populations but existing populations had also been expanding rapidly over that time (Watkins and McNee 1985).

Control of Typha

Preventing establishment of seedlings is vital to limiting spread of the weed. Trials at Lake Forrestdale found cultivating seedling populations late in autumn, when most seed has germinated, effectively prevented seedling establishment. Although water levels are at their lowest at this time in Perth, the ground was still soft. A Honda trike with balloon tyres dragging a piece of weld mesh was used to cultivate the population (Watkins and McNee 1985).

Maintaining a cover of native species in fringing vegetation will keep light levels down and prevent germination of seeds. *Juncus* species will displace seedlings.

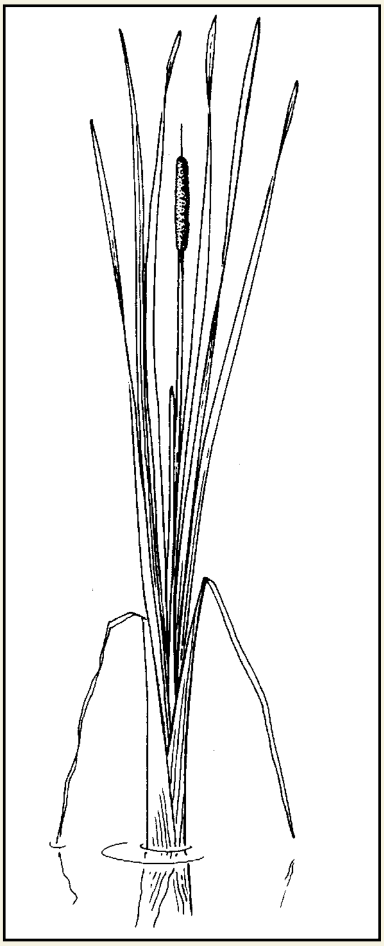
Cutting shoots 15 cm below the water surface two to three times in one season when plants are actively growing, but before seeds are fully formed, can reduce a stand by 95-99 % (Motivans and Apfelbaum 2002).

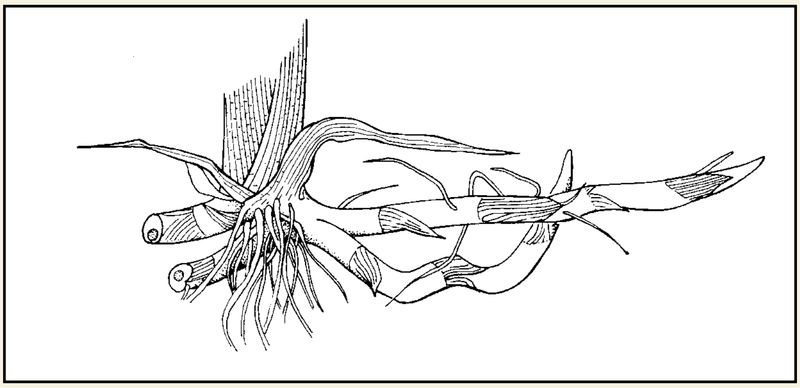
Plants generally resprout following fire unless fire kills rhizomes. Case studies looking at control through burning (low intensity) dense infestations of *Typha* species in North America, in late winter, have shown that under certain conditions a 70 % reduction in populations can be achieved (Snyder 1993).

As Typha often grows in water, chemical application is sometimes inappropriate. Roundup Biactive (360 g/L) at 13 mL/L is registered for use on Typha species in Tasmania. Apply in the period between male flowers opening, and six weeks after female flowers emerge. Avoid producing run-off or spray drift (DPIWE 2001).

Typha orientalis is an aggressive coloniser of wetlands on the Swan Coastal Plain. Effective management requires an integrated approach

- Keeping disturbance out of intact plant communities prevents establishment of seedlings.
- Controlling seedlings as a priority prevents establishment of new populations.
- Removing emerging flower spikes from established populations limits seed production and spread.
- Using both physical and chemical techniques is essential for effective control of established populations.





Rhizome of Typha orientalis

Annual Broadleaf Herbs, Sedges and Succulents Weed Management Table

Species	Common name	Timing of seed germination	Growing season	Flowers	Dispersal agent	Seedbank persistence (years)	Can be biennial
Arctotheca calendula	Cape Weed	after rains	win/spr	Aug-Nov	wind	some dormancy 8+?	y
Bellardia trixago	White Bartsia	autumn/winter	win/spr	Sep-Jan	wind		
Cakile maritima	Sea Rocket	mostly spring but any time after rain	win/spr	Jan-Dec	wind, water	2+	y
Carduus pycnocephalus	Slender Thistle	up to 6wks after autumn rains	win/spr	Oct-Dec	wind, water, birds	10+	
Carduus tenuiflorus	Sheep Thistle	up to 6wks after autumn rains	win/spr	Sep-Nov	wind, water, birds	10+	
Carthamus lanatus	Saffron Thistle	autumn and early winter. staggered south west W.A	win/spr	Dec-Apr	water, adhesion	8	
Centranthus macrosiphon	Pretty Betsy		win/spr	Aug-Nov	limestone gravel, wind?	short?	
Chenopodium album	Fat Hen	after rains	all year	Mar-Apr/Oct-Dec	birds, machinery	20-40	
Cirsium vulgare	Spear Thistle	autumn mostly	win/spr	Jan-Dec	wind, water, machinery	30+	y
Conyza albida	Tall Fleabane	autumn/winter/spring	win/spr	Dec-Feb	wind		
Conyza bonariensis	Flaxleaf Fleabane	autumn/winter/spring	win/spr	Dec-Feb	wind		
Crepis capillaris	Smooth Hawks Beard		win/spr	Nov-Jan	wind		y
Crepis foetida	Stinking Hawks Beard		win/spr	Nov-Jan	wind		y
Cucumis myriocarpus	Prickly Paddy Melon		sum	Jan-May	birds, machinery		
Dischisma arenarium			win/spr	Aug-Nov			
Dischisma capitatum	Wolly Dischisma		win/spr	Aug-Sep			
Dittrichia graveolens	Stinkwort		sum	Jan-Apr	wind, animal		
Echium plantagineum	Patersons Curse	all year	win/spr	Sep-Jan	water, machinery	6 (most in 2)	y
Emex australis	Doublegee	all year	win/spr	Jul-Oct	tyres, water, machinery	4+	
Erodium botrys	Long Storksbill	mainly autumn/winter but spring/ summer if moisture is available	win/spr	Aug-Nov		3+	
Euphorbia peplus	Petty Spurge	autumn to spring	win/spr	Jul-Jan			
Fumaria capreolata	Climbing Fumitory	autumn to spring	win/spr	Aug-Nov			
Fumaria muralis	Wall Fumitory	autumn to spring	win/spr	Jun-Dec		20+	
Hypochaeris glabra	Flat Weed	autumn/winter	win/spr	Jan-Dec	wind		y
Hypochaeris radicata		autumn	win/spr	Jan-Dec	wind	<1	y
Isolepis hystrix			win/spr	Nov	wind, machinery		

Suggested methods of management and control	Similar natives often mistaken for weeds	Reference
Colonises bare soil and disturbed sites. Lontrel® 6 mL/10 L (300 mL/ha) in early growth stages. Glyphosate 0.2 % will control at all growth stages.		146, 53, 96, 115, 101, 167, 242, 222
Colonises disturbed wetlands. Hand remove isolated plants before seed set. Spot spray 0.2 % glyphosate.		167, 242, 222
		300, 207, 167, 242
Seedlings establish in bare open ground so establish desirable vegetation cover. Hand remove isolated plants through spring and early summer. Glyphosate applied with a rope wick provides good control **or** spot spray Lontrel® 10 mL in 10 L water + 25 mL wetting agent. Control at rosette stage.		300, 248, 91, 121, 228, 167, 242
as for Slender Thistle		300, 248, 91, 228, 167, 242
as for Slender Thistle		300, 248, 96, 147, 251, 145, 120, 228, 167, 242
Hand remove small populations. Spray metsulfuron methyl 0.1 g/15 L (2 g/ha) + wetting agent.		300, 101, 167, 242
Highly susceptible to mowing before flowering. Requires bare ground for establishment and persistence. Herbicide application most effective in early growth stages.		19, 228, 167, 242
Seedlings establish in bare open ground so establish desirable vegetation cover. Glyphosate 0.5 % provides effective control of seedling and adult plants **or** Lontrel® 6 mL/10 L (300 ml/ha) + wetting agent, rosette to early flowering.		248, 96, 167, 242, 222
Does not compete well under high plant density or cover. Requires disturbance to establish and persist. Establish desirable vegetation.		333, 325, 167, 242
Does not compete well under high plant density or cover. Requires disturbance to establish and persist. Establish desirable vegetation.		300, 333, 325, 167, 242
Spot spray 1 % glyphosate + Pulse® **or** 10 mL Lontrel® in 10 L of water + 25 mL Pulse®.		167, 242, 222
Spot spray 1 % glyphosate + Pulse® **or** 10 mL Lontrel® in 10 L of water + 25 mL Pulse® .		300, 167, 242, 222
Hand remove isolated plants before flowering. Not killed by glyphosate. Spot spray 2 mL Garlon® in 10 L of water + 25 mL wetting agent.		248, 167, 242, 222
Spot spray 0.2 % glyphosate.		167, 242
Spot spray 0.2 % glyphosate.		167, 242
Hand remove isolated plants before flowering. Slash very close to ground (can resprout).		248, 167, 242
Slashing or mowing can cause out of season flowering and seed production. Spot spray in late autumn when most seed has germinated for the year with 0.5g/10 L chlorsulfuron + wetting agent-this will help prevent further germination. Glyphosate will control existing plants.		229, 248, 96, 257, 167, 242, 222
Spot spray plants with 1 % Grazon® . Seed produced at early stage. Any control program must aim at killing all plants shortly after emergence and must continue for a number of years. Spot spray with glyphosate 0.5-0.7 % to kill existing plants but bare soil quickly reinfested.		133, 248, 286, 167, 242, 222
Lontrel® at 6 mL/10 L (300 mL/ha) + wetting agent applied before flowering or Verdict 520® at 1.5 mL/ 10 L (75 mL/ha) + wetting agent.	*E. cygnorum*	12, 228, 222, 101, 167, 242, 222
Colonises degraded sites; spray metsulfuron methyl 0.1 g/15 L (2.5 g/ha) + wetting agent or glyphosate 0.5 %.		101, 167, 242
Colonises degraded sites; spray metsulfuron methyl 0.1 g/15 L (2.5 g/ha) + wetting agent or glyphosate 0.5 %.		101, 167, 242
Colonises degraded sites; spray metsulfuron methyl 0.1 g/15 L (2.5 g/ha) + wetting agent or glyphosate 0.5 %.		254, 62, 101, 167, 242
Rosettes wiped with glyphosate 30 % provides effective control. Dense infestations - 25 mL wetting agent + 10 mL Lontrel® in 10 L of water.		300, 228, 222, 167, 242
Rosettes wiped with glyphosate 30 % provides effective control. Dense infestations - 25 mL wetting agent + 10 mL Lontrel® in 10 L of water.		300, 54, 228, 167, 242
		167, 242

Annual Broadleaf Herbs, Sedges and Succulents Weed Management Table

Species	Common name	Timing of seed germination	Growing season	Flowers	Dispersal agent	Seedbank persistence (years)	Can be biennial
Lactuca serriola	Prickly Lettuce	autumn to spring	sum	Oct-Feb	wind		y
Lupinus angustifolius	Narrowleaf Lupin	autumn/winter	win/spr	Jul-Nov		little dormancy	
Lupinus cosentinii	Sand Plain Lupin	autumn	win/spr	Aug-Nov		some dormancy	
Malva parviflora	Small Flowered Mallow	spring to autumn	win/spr	Jul-Nov	soil, water	100?	y
Medicago polymorpha	Burr Medic	autumn/winter	win/spr	May-Nov	animal, adhesion	5+	
Melilotus indicus	King Island Meliot		win/spr	Aug-May	water, wind	20+?	y
Mesembryanthemum crystallinum	Common Ice Plant	autumn/winter or after rains	win/spr	Sep	fleshy fruit-animal ingestion	22?	y
Osteospermum clandestinum	Stinking Roger	autumn/winter	win/spr	Oct-Dec	wind		
Parentucellia viscosa	Sticky Bartsia		win/spr	Aug-Jan	wind, water, machinery		
Petrorhagia velutina	Velvet Pink		win/spr	Aug-Dec			
Portulaca oleracea	Pigweed	most in autumn	sum	Feb-May	wind, water, soil, birds	40	
Ranunculus muricatus	Sharp Buttercup		win/spr	Aug-Dec			
Raphanus raphanistrum	Wild Radish	bulk after autumn rains but sporadic throughout year	all year	Apr-Nov	wind, water, machinery	20	y
Senecio elegans			win/spr	Sep-Mar	wind		
Senecio vulgaris	Groundsel	all year	win/spr	Jul-Feb	wind	5	
Silene gallica	French Catchfly		win/spr	Jul-Dec			
Solanum americanum	Glossy Nightshade		win/spr	Mar-Dec	birds, water, soil, machinery		
Solanum nigrum	Black Nightshade	spring/summer	win/spr	Jan-Dec	birds, water, soil, machinery	5+	y
Sonchus asper	Prickly Sowthistle	all year	win/spr	Sep-Dec	wind	1-2	y
Sonchus oleraceus	Sowthistle	autumn/winter	win/spr	Sep-Dec	wind	1-2	y
Symphyotrichum subulatum	Bushy Starwort		sum	Dec-Mar	wind		
Tribulus terrestris	Caltrop	all year	all year	Jan-Dec	tyres, water, machinery	several	
Trifolium spp	Clovers		win/spr	Sep-Dec	soil, water	some dormancy	
Ursinia anthemoides	Ursinia		win/spr	Jul-Dec	wind, adhesion		
Vicia sativa	Common Vetch	autumn/winter	win/spr	Jul-Dec	birds, horses, sheep ingest	some dormancy	

Suggested methods of management and control	Similar natives often mistaken for weeds	Reference
Colonises disturbed wetland sites.		316, 167, 242
Hand remove scattered plants. Spray dense infestations metsulfuron-methyl 0.1 g/15 L (2-3 g/ha) + wetting agent **or** Lontrel® 6 mL/10 L (300 mL/ha) + wetting agent to late flowering (will prevent seed set).		101, 222, 167, 242
Hand remove scattered plants. Spray dense infestations metsulfuron-methyl 0.1g/15 L (2-3 g/ha) + wetting agent.		258, 101, 222, 167, 242
Hand remove isolated plants. Chemical control only effective at early growth stages.	*M. australiana*	197, 222, 167, 242,
25 mL of wetting agent + 10 mL of Lontrel® in 10 L of water provides effective control in early winter **or** metsulfuron methyl 0.1 g/10 L + wetting agent.		200, 228, 167, 242
Weed of highly disturbed bushland. If slashing cut below lowest branch axil to prevent resprouting.		300, 335, 167, 242
Hand remove isolated plants through spring and early summer. Spot spray with 0.5 % glyphosate **or** Lontrel® 10 mL/ 10 L (500 mL/ha).		334, 316, 167, 242, 222
Spot spray with glyphosate 0.5 % before flowering.		222, 167, 242, 222
Spot spray with glyphosate 0.5 % before flowering.		167, 242, 222
		167, 242
Hand remove before flowering. Will shoot from stem fragments under moist conditions. Spot spray 0.5 % glyphosate.		217, 167, 242, 222
	R. amphitrichus, R. colonorum	167, 242
Weed of highly disturbed edges. Hand remove isolated plants several times over the year. Spot spray 1% glyphosate before flowering.		248, 66, 228, 167, 242
Only persists in disturbed sites. Lontrel® at 10 mL in 10 L of water + 25 mL wetting agent applied before stem elongation in late spring.		30, 167, 242, 222
Only persists in disturbed sites. Lontrel® at 10 mL in 10 L of water + 25 mL wetting agent applied before stem elongation in late spring.		300, 337, 167, 242, 222
		167, 242
Weed of disturbed sites. Shade reduces seed production. Hand weed small infestations.		300, 167, 242
Weeds of disturbed sites. Shade reduces seed production. Hand weed small infestations.		300, 141, 167, 242
Slashing often ineffective as flowers continue to be produced. Rosette stage preferred time for effective chemical control. Lontrel® at 10 mL in 10 L of water + 25 mL wetting agent.	*S.hydrophilus* Native Sowthistle	300, 11, 168, 167, 242, 222
Slashing often ineffective as flowers continue to be produced. Rosette stage preferred time for effective chemical control. Lontrel® at 10 mL in 10 L of water + 25 mL wetting agent.		300, 11, 168, 167, 242, 222
Colonises disturbed wetlands. Hand remove isolated plants before seed set.		167, 242
Glyphosate 1 % effective on seedlings. Exclude people and close tracks to stop spread. On bare tracks diesel can be used to kill plants and penetrate and destroy seed in surface soil.		248, 167, 242
Hand remove isolated plants before flowering. Spot spraying Lontrel® 10 mL/10 L + wetting agent in early winter before flowering provides effective control.		228, 167, 242
		167, 242
Colonises bare disturbed sites. Can smother native plants. Lontrel® 10 mL/10 L + wetting agent provides effective control in early growth stages **or** metsulfuron methyl 0.1 g/ 10 L + wetting agent.		1, 228, 222, 167, 242, 222

Perennial Broadleaf Herbs, Sedges and Succulents Weed Management Table

Species	Common name	Flowering	Reproductive unit	Seedbank persistence (years)	Dispersal agent
Acetosella vulgaris	Sorrel	Aug-Dec	**seed,** root fragment	long	wind, water, animal, soil
Agapanthus praecox	Agapanthus	Oct-Dec	rhizome, **seed**	short	soil
Agave americana	Century Plant	Dec-Jan	**seed,** suckers		wind, water
Alternanthera pungens	Khaki Weed	Mar-Jul	stem and root fragment, **seed**	many	soil, animal (adhesion)
Arctotheca populifolia	Dune Arctotheca	Jun-Jan	seed		wind, soil
Arctotis stoechadifolia	Arctotis	Sep-Jan	root fragment	germination of seed rare	soil
Argyranthemum frutescens	Marguerite	Jul-Oct	seed		
Asphodelus fistulosus	Onion Weed	Jun-Oct	seed	many	wind, machinery, water
Berkheya rigida	African Thistle	Oct-May	**seed,** stem and root fragments	many	adhesion, soil
Canna x generalis	Canna Lily	Nov-Mar	rhizome, seed?		soil, bird
Carex divisa	Divided Sedge	Sep-Dec	seed?		water?
Carpobrotus aequilaterus	Angular Pigface	Aug-Nov	**seed,** stem fragments		
Carpobrotus edulis	Pigface	Aug-Nov	**seed,** stem fragments	2 +	rabbits, birds (ingestion)
Centranthus ruber	Red Valerian	Oct-Mar	**seed,** rhizome		soil
Chenopodium ambrosioides	Mexican Tea	Mar-Jul	seed		soil, machinery, water
Cyperus congestus	Dense Flat Sedge	Jul-Oct			
Cyperus eragrostis	Umbrella Sedge	Jun-Jul	**seed,** rhizome		soil, water
Cyperus polystachyos	Bunchy Sedge	Dec-Jul			
Cyperus rotundus	Nut Grass	Apr-Jul	seed, **tubers, rhizome**	seed viability low, tubers longevity up to 10	soil, water (flooding), wind
Epilobium ciliatum	Willow Herb	Oct-Jan	**seed,** crown fragments	short?	wind, soil
Euphorbia paralias	Sea Spurge	Oct-Jun	**seed,** root fragments	2 + in salt water	explosive, water, sand, wind
Euphorbia terracina	Geraldton Carnation Weed	Aug-Dec	seed	3-5	explosive, birds, ants, limestone, machinery
Foeniculum vulgare	Fennel	Jul-Jan	root fragments, seed		soil, machinery ,water
Hypericum perforatum	St John Wort	Mar-0ct	stem fragments, **seed,** rhizome	10	water, soil, machinery, animals (adhesion and ingestion)
Isolepis prolifera	Budding Club Rush	Oct-Jan	seed? stem fragments		water
Juncus acutus	Spiny Rush	Oct-Dec	**seed,** crown fragments		water, machinery
Juncus microcephalus		Nov-Feb	seed		water, machinery
Limonium companyonis	Statice, Sea Lavender	Nov-Feb	seed		
Limonium sinuatum	Statice, Sea Lavender	Sep-May	seed		
Lotus uliginosus	Greater Lotus	Nov-Mar	seed, rhizome		water, soil

Reproductive unit: bold*=main mechanism of dispersal.* ***Seedbank perisistence:*** *long=5+ years short= months to 1 year*

Some suggested methods of management and control	Similar natives often mistaken for weeds	Reference
Spot spray with 0.5 % glyphosate or metsulfuron methyl 0.2 g/10 L + 25 mL Pulse® .		248, 21, 228, 167, 242
Dig out taking care to remove all bulbs. Remove and burn or deep bury flower heads to stop spread of seed. Spray with 1 % Grazon® just before flowering.		21, 101, 167, 242
Dig out small infestations. Stem inject into base of leaves 1 partTordon®/ 5 parts diesel. (flowers only once, after 10 to 15 years, then dies)		21, 167, 242
Difficult to control as it is a true deep-rooted perennial. Cut roots well below surface. Cultivation can spread plant fragments. Spot spray with 1 % glyphosate before flowering.	*A. nodiflora*	248, 222, 167, 242
Difficult to hand pull and resistant to chemicals, it is short-lived. Lontrel® 10 mL/10 L (500 mL/ha) + Pulse® in early growth stages. Glyphosate 1% will control at all growth stages.		143, 102, 167, 242, 222
		30, 167, 242
Hand pull small infestations.		143, 102, 167, 242,
Hand pull small infestations. Metsulfuron-methyl 0.1 g /10 L +100 mL spray oil when flowering.		248, 228, 167, 242
Dig out and destroy single plants before flowering. Suggest Lontrel® 10 mL/10 L + wetting agent at early rosette stage **or** 0.5 % glyphosate.		30, 248, 222, 167, 242
Hand pull small infestations. Cut stems to ground level, paint 10 % glyphosate on larger infestations.		241, 167, 242
Physical control where only scattered plants occur. Try 1 % glyphosate.		167, 242, 222
As for *C. edulis*?	*C. virescens*	167, 242
Roll up large mats removing all roots (shallow-rooted) and stem fragments. Follow up with removal of any germinating plants. Spray with glyphosate at label rates.		13, 83, 84, 167, 242
Suggest metsulfuron methyl 0.15 g/10 L (5 g/ha) + Pulse® before flowering.		300, 101, 167, 242
Hand remove small populations (use gloves); Suggest metsulfuron methyl 0.7 g/10 L (20 g/ha) + Pulse® before flowering or 1 % glyphosate + Pulse®.		102, 167, 242
Try 1 % glyphosate + Pulse®.		167, 242, 222
Try 1 % glyphosate + Pulse®.		167, 242, 222
Try 1 % glyphosate + Pulse®.		167, 242, 222
Intolerant of dense shade - apply glyphosate at label rate before the fifth leaf stage after this time herbicide is not translocated to tubers. Difficult to control.		332, 248, 241, 317, 167, 242
Spray seedlings with glyphosate; established plants will resprout from crown after glyphosate treatment. Seedlings normally only establish on bare moist soil.	*E. billardiereanum, E. hirtigerum*	248, 96, 167, 242
Hand remove small isolated infestations. Long tap root. Consider possible dune erosion.		248, 330, 167, 242
Large infestations - spot spray- with herbicide metsulfuron methyl 0.1 g/15 L or metsulfuron methyl + 1 % glyphosate before flowering. Follow-up with hand removal for at least five years.		98, 173, 267, 248, 167, 242
Usually found in very disturbed sites; persistent and difficult to eradicate. Spot spray with 1.5 % glyphosate **or** metsulfuron methyl 0.7 g/10 L (20 g/ha) + Pulse ®. On older plants apply just before flowering. Follow up on seedlings. Seed germinates throughout year; plants don't flower until around 2 years.		23, 102, 167, 242
Seedlings establishment restricted by soil cover, litter and competition. Spot spray at flowering (50 % bud - 50 % open flowering - do not spray after 50 % green bud) with Grazon® (triclopyr + picloram) at label rates. Biological control available from CSIRO.		55, 56, 8, 341, 57, 167, 242
		167
Establish native vegetation cover; dig out isolated plants; spray 2 % glyphosate-repeat application six weeks later. Burning plants after they have been knocked back by herbicide increases kill rate. Consider possibility of erosion.		6, 241, 248, 167, 242
Dig out isolated plants.	*J. holoschoenus*	167, 242
		248, 167, 242
Hand remove small patches.		167, 242
Weed of highly disturbed areas. Spot spray Lontrel® at 10 mL/10 L + 25 mL wetting agent.		101, 228, 167, 242

 Perennial Broadleaf Herbs, Sedges and Succulents Weed Management Table

Species	Common name	Flowering	Reproductive unit	Seedbank persistence (years)	Dispersal agent
Malva dendromorpha	Tree Mallow	Aug-Dec	seed	long	birds-(adhesion and ingestion)
Myosotis sylvatica	Forget-Me-Not	Sep-Dec	seed		animals (adhesion), soil
Oenothera drummondii	Beach Evening Primrose	Feb-Jun	seed	*O. biennis* up to 80.	
Oenothera laciniata		May-Jan	seed		
Oenothera mollissima		Nov-Mar	seed		
Oenothera stricta		Jan-Nov	seed		
Parietaria judaica	Pellitory	Dec-Jan	**seed,** root fragments		water, wind, soil, animals (adhesion), ants
Pelargonium capitatum	Rose Pelargonium	Aug-Dec	**seed, root fragments**		wind, water, soil
Phytolacca octandra	Red Ink Plant	Jan-Mar	seed	short	birds (ingestion)
Plantago lanceolata	Ribwort Plantain	Nov-mar	**seed,** stem fragments	some dormancy	soil, water
Plantago major	Greater Plantain	Oct-Feb	seed	up to 40	soil, water
Rumex brownii	Swamp Dock	Apr-May	**seed, root fragments**	80+ (some species)	animals, soil, machinery
Rumex conglomeratus	Clustered Dock	Oct-Feb	**seed, root fragments**	long	animals, soil, machinery
Rumex crispus	Curled Dock	Jul-Dec	**seed,** root fragments	20+	animals, soil, machinery
Sagina procumbens	Spreading Pearlwort	Jul-Sep	seed, stem and root fragments	long	probably wind
Senecio glastifolius	Holly-leafed Senecio	Aug-Oct	seed	some persistence	wind, soil, machinery
Trachyandra divaricata	Dune Onion Weed	Aug-Nov	seed	light induces dormancy	wind
Trifolium repens	White Clover	Jul-Jan	**seed,** stem fragments, stolons	25+	wind, water, birds, animal (ingestion)
Typha orientalis	Typha	Oct-Dec	**seed,** rhizomes		wind, water, soil
Vinca major	Blue Periwinkle	Aug-Nov	stem fragments, stolons	Seed rarely matures	soil, machinery, water?

Reproductive unit: bold*=main mechanism of dispersal.* ***Seedbank perisistence:*** *long=5+ years short= months to 1 year*

Some suggested methods of management and control	Similar natives often mistaken for weeds	Reference
Biennial, rapidly replacing the native *Malva* on islands off the coast of Perth. Cut to ground and paint stump with glyphosate. Weed mat will prevent germination of seedlings.	*M. australiana*	274, 167, 242, 197
Try 0.5 % glyphosate + Pulse®.		167, 242, 222
Control in seedling stage, older plants resistant to herbicide. Relatively tolerant of glyphosate. Hand remove small populations in areas not susceptible to erosion. Spot spray chlorsulfuron 0.4 g/10 L + spray oil.		300, 38, 49, 228, 167, 242, 222
Control in seedling stage, older plants resistant to herbicide. Relatively tolerant of glyphosate. Hand remove small populations - remove entire root stystem. Spot spray chlorsulfuron 0.4 g/10 L + spray oil.		300, 38, 49, 228, 167, 242, 222
Control in seedling stage, older plants resistant to herbicide. Relatively tolerant of glyphosate. Hand remove small populations - remove entire root stystem. Spot spray chlorsulfuron 0.4 g/10 L + spray oil.		300, 38, 49, 228, 167, 242, 222
Control in seedling stage, older plants resistant to herbicide. Relatively tolerant of glyphosate. Hand remove small populations - remove entire root stystem. Spot spray chlorsulfuron 0.4 g/10 L + spray oil.		300, 38, 49, 228, 167, 242, 222
Hand pull isolated plants. Regular spot spraying with 1 % glyphosate is reported to give effective control in Australia. Resistance to glyphosate reported from the Mediterranean.	*P. debilis*	248, 18, 167, 242
Hand pull isolated plants taking care to remove entire stem - will reshoot from below ground level. Spot spray metsulfuron methyl 5 g/ha + Pulse®. Easy target after fire.		300, 101, 167, 242
Dig out isolated plants - cut root at least 5 cm below ground. Spray with 1 % glyphosate + Pulse®.		300, 21, 101, 167, 242, 222
Spray in early stages of growth with 1 % glyphosate.	*P. debilis, P. drummondii, P. exilis*	300, 336, 167, 242, 222
Spray in early stages of growth. Suggest 1 % glyphosate.		30, 336, 151, 167, 242
Spot spray with 1 % glyphosate in early bud stage, cultivation of older plants will spread root fragments.	*R. dumosus, R. drummondii*	96, 248, 326, 167, 242
Spot spray with 1 % glyphosate in early bud stage, cultivation of older plants will spread root fragments.		96, 248, 326, 167, 242
Spot spray with 1% glyphosate in early bud stage, cultivation of older plants will spread root fragments.		96, 248, 326, 167, 242
Hand remove small infestations. Seed generally does not move far from parent plants. Boiling water reported to destroy 99 % of soil seed bank.		130, 167, 242
Hand remove small infestations. Lontrel® at 10 mL/10 L (500 mL/ha) + wetting agent just before stem elongation in spring.		339, 228, 167, 242
Wipe with 50 % glyphosate solution before flowering. Dense infestations in degraded areas spot spray 0.4 g chlorosulfuron plus 25 mL wetting agent in 10 L of water when plants actively growing.		300, 153, 25, 228, 167, 242, 222
Spot spray with 1 % glyphosate before flowering. Lontrel® 3 mL/10 L (150 mL/ha) up to 6 leaf stage.		77, 102, 167, 242
Roundup Biactive® (360 g/L) at13 mL/L. Apply in the period between male flowers opening, and 6 weeks after female flowers emerge. Avoid producing run-off or spray drift. Cutting shoots 15 cm below the water surface two to three times in a season when actively growing, but before seeds are formed, greatly reduces stands.	*T. domingensis*	230a, 96, 167, 242
Hand pull small infestations. Spray larger areas with 2 % glyphosate + 2 % Pulse® ; spray when plants have approximately 5 cm new growth in 8-12 weeks - repeat applications will be required.		21, 22, 228, 167, 242, 222

Chapter 6 Trees, Shrubs and Climbers

The Woody Weeds

The term "woody weed" refers to any woody perennial tree, shrub or climber that has established within bushland outside its natural range. Unlike the herbaceous plants covered in previous chapters, woody plants have secondary growth, which means their stems continue to lay down new tissue increasing in girth even after they stop increasing in height.

Most woody weeds recorded around the world were deliberately introduced as ornamentals or forestry species (Binggeli *et al.* 1998). Many of the species found in south west Western Australia come from southern Africa, South America and the Mediterranean region. Planting of 'Australian natives' in parks and bushland, has also resulted in the naturalisation of numerous weedy Australian species. Of the 81 tree and shrub species recorded as environmental weeds of the Swan Coastal Plain and Jarrah Forest, 39 % are eastern Australian species (Keighery 1999a). Given the opportunity, even Western Australian species can become weedy outside their natural range (Box 6.1).

The biology of woody plants varies considerably. Most reproduce by seed – but not all. Some are deciduous, some evergreen. Many resprout when felled, some sucker, others simply die. Woody species may retain their fruit in the canopy, releasing it when the tree is damaged, or shed it as soon as it is ripe. Mammals, birds, insects, wind, water or gravity may disperse fruit. Seed may remain viable for years, or only weeks, and plant lifespan can vary from several to hundreds of years. Some woody species produce toxins that inhibit growth of other plants. The toxins produced by the Tree-of-heaven (*Ailanthus altissima*) are so strong their potential use as a natural herbicide has been researched (Lin *et al.* 1995).

Common characteristics that make woody weeds highly competitive (Binggeli *et al.* 1998, Buist *et al.* 2000) include:

- Fast growth.
- Early maturity and prolific seeding.
- High seed germinability.
- Readily germinate and grow within shady conditions.
- Ability to grow at high densities.
- Resprouting or suckering response.
- Lack of seed and plant predation in the naturalised habitat.
- Resilience to a range of environmental conditions.
- A rapid response to changes in space, light, nutrient or water availability.

As a group the woody weeds pose several problems to bushland managers. They are often large, both difficult to dig out and to spray without causing damage to the surrounding vegetation. Their removal can result in the loss of desirable shade and cause a considerable increase in the space, light and nutrients available to other weeds that might be present. The act of removal itself can damage surrounding vegetation and spread propagules. This chapter discusses these problems and looks at some of the different treatment options available. In particular it highlights the relationship between treatment approach and the plant's ability to resprout and sucker.

Box 6.1 Western Australian natives can be weeds too.

"*In Western Australia thirty five species of Western Australian plants have become naturalised, largely outside their ranges, from plantings*" (Keighery 2002b). It is important to emphasise the use of locally collected material (seed or cuttings) when planting in or near bushland areas. Likewise, correct identification of plants from which material is collected is also essential.

Table 1. Some Western Australian natives known to have naturalised outside their native range (adapted from Keighery, G., unpublished report).

Acacia acuminata (Jam)
Acacia blakelyi
Acacia lasiocalyx
Acacia microbotrya (Manna Wattle)
Acacia myrtifolia
Allocasuarina huegeliana (Rock Sheoak)
Banksia caleyi (Caley's Banksia)
Callitris glaucophylla
Callitris preissii (Rottnest Island Pine)
Calothamnus chrysantherus (Clawflower)
Calothamnus graniticus
Calothamnus quadrifidus (One-sided Bottlebrush)
Calothamnus validus (Barrens Clawflower)
Ceratopteris thalictroides
Diplolaena dampieri (Southern Diplolaena)
Eucalyptus camaldulensis (River Red Gum)
Eucalyptus conferruminata (Bald Island Marlock)
Eucalyptus erythrocorys (Illyarrie Gum)
Eucalyptus todtiana (Coastal Blackbutt)
Grevillea leucopteris (White Plume Grevillea)
Hakea costata (Ribbed Hakea)
Hakea francisiana (Emu Tree)
Hakea pycnoneura
Hibbertia cuneiformis (Cut-leaf Hibbertia)
Kunzea baxteri
Melaleuca nesophila
Melaleuca pentagona
Melia azedarach (Cape Lilac)
Verticordia monadelpha (Woolly Featherflower)

Actual or potential serious weeds
Agonis flexuosa (Peppermint)
Chamelaucium uncinatum (Geraldton Wax)
Melaleuca lanceolata (Rottnest Tea Tree)

Illustration provided by: IFAS, Centre for Aquatic Plants University of Florida, Gainesville, 1996

Impacts

Invasive woody species can have profound effects on the structure and diversity of the invaded bushland. Weedy trees and shrubs often form dense stands, shading out and preventing the germination and establishment of native species (Gleadow and Ashton 1981, Gleadow 1982, Weiss and Noble 1984, Rose and Fairweather 1997, Goodland *et al.* 1998, Mullett 2002). Over a 25 year period at Croydon North in Melbourne, scattered plants of Sweet Pittosporum (*Pittosporum undulatum*) coalesced into a dense stand, obliterating nearly all the original understorey (Gleadow and Ashton 1981). Closer to home, on the Darling Scarp east of Perth, stands of eastern Australian Acacias, including Cootamundra Wattle (*Acacia baileyana*), Silver Wattle (*Acacia dealbata*) and Flinders Range Wattle (*Acacia iteaphylla*), form dense stands in the understorey of the Jarrah Forest. The establishment of dense weed infestations also impact on the fauna. Habitat and food sources are lost, which may lead to decreases in native animal diversity.

It may only require one or two plants to establish and reach maturity for the source of an infestation to form. The seed rain that follows, coupled with the ability to germinate in shady conditions and/or take rapid advantage of disturbance events, is enough to allow dense establishment of the plant. In Kings Park and Botanic Garden, Perth, a small number of *Acacia lasiocalyx* were planted on the edge of bushland around 1967. A wildfire in 1989 resulted in mass germination of the species and it was realised this Western Australian Wheatbelt species had become a serious weed. By 1993, when the non-sprouting trees were cut out by a group of dedicated volunteers, *A. lasiocalyx* had covered 0.6 hectares of the park's bushland area (Dixon 2001, Dixon pers. comm. 2002).

A dense infestation of Acacia lasiocalyx in Kings Park Bushland. (Photograph by Bob Dixon).

Mechanisms of spread

Woody plants may reproduce by seed, or create clones from vegetative fragments or propagules. Dispersal of propagules, over short or long distances, followed by successful establishment results in the spread of the plant.

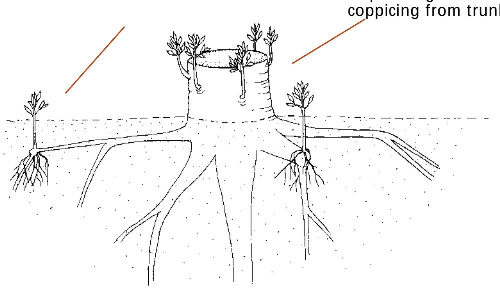
- *Birds, insects and mammals* spread the seeds of many invasive woody species. Seeds of Brazilian Pepper (*Schinus terebinthifolius*), Edible Fig (*Ficus carica*) and Blackberry (*Rubus* spp) are all ingested by birds and germinate in their droppings. Finding weed species growing at the base of perching trees is a good indication that these particular weeds are spread by birds (Gleadow 1982, Blood 2001). Propagules also attach to feathers and fur or can be carried by ants (many *Acacia* species).
- *Wind* is an effective disperser of seed especially if an individual plant emerges above the canopy (eg. Tamarisk, Sheoaks and Eucalypts). Dispersal distance is considerably less than with bird-disseminated species.
- *Water* can carry propagules down stream and, during floods, to distant sites. The seeds of many *Acacia* species, stems of Willows (*Salix* spp), and aerial tubers of Madeira Vine (*Anredera cordifolia*) are all carried by water.
- *Garden rubbish* dumped in bushland introduces various weed propagules. Cuttings of Australian natives, especially eastern Australian Bottlebrush (*Callistemon*) and Wattle (*Acacia*) species, are commonly dumped in bushland under the misguided belief that they came from there!
- *Planting* of non-local tree species within bushland can also be the source of woody weed invasions (eastern Australian species and Western Australian species planted outside their natural range).
- *Individual* plants may spread locally by vegetative reproduction - stem layering or root suckering.

Resprouting, suckering and apical control

Resprouting and suckering are mechanisms by which many woody plants resist or recover from fire, storm or grazing damage.

Suckering is the formation of sprouts from adventitious buds in the lateral roots. Suckers arise most often at root branch intersections, areas of root irregularity or points of injury. Individual plants form as the sucker develops its own root system and old root connections are broken. Some species sucker in response to crown removal or root damage.

Resprouting, or coppicing, refers to the growth of shoots from dormant buds (epicormic buds) in the stem or root crown after the canopy has been removed or damaged. The ability to sprout can be age-dependent. Epicormic buds may not be laid down until a plant reaches a certain maturity. In some species the woody rootstock contains epicormic buds and is termed a lignotuber (common in Eucalypts).



In woody plants, the term apical dominance describes the control the shoot tip has over the current year's growth (Cline 1997). When apical dominance is removed, as in tip pruning, the side buds are able to develop and the plant becomes bushier. On a whole tree scale, **apical control** describes the inhibition of lateral branch growth by the top portion of the tree crown, the canopy (Cline 1997, Wilson 2000). When the crown is cut off, apical control is removed and epicormic buds in the lower trunk and root crown are free to sprout. The sprouting response is due, in part, to removal of plant growth hormones, in particular auxins (Cline 2000). However, release of carbohydrates, nutrients and water previously used by the canopy, combined with increased light and space also play a role (Cline 2000). Suckering from lateral roots may also occur with the release of apical control. This has been shown for a number of species including Quaking Poplar (*Populus tremulus*), Black Locust (*Robinia pseudoacacia*), Tree-of-heaven and Lantana (*Lantana camara*) (Anon. 1999, Binggeli *et al.* 1998, Converse 1984b, Converse 1987).

The implication of apical control for management is simple – removal of the crown above epicormic buds enhances resprouting and, in many species, suckering. Herbicide treatment is required to kill these species. Species known to sucker should be treated using basal bark or stem injection methods (see following). These methods allow systemic herbicides to be translocated around the plant without the release of apical control which would initiate the suckering response.

Management and control

When managing woody weeds the approach taken and the techniques used will depend on: The size and distribution of the infestation, the species in question, the plant age and size, the presence of other invasive weeds, the impact on other plants and animals, the sensitivity of the area and the size and skills of the labour force.

The general approach

- As with other weed groups, baseline maps illustrating the distribution of target species allow for strategic planning of control and follow-up work.
- Isolated trees/shrubs/climbers and small infestations in good bushland should be removed first, preferably before the year's seed crop has ripened. Modeling has shown that eradicating small founding populations slows the overall invasion process (Moody and Mack 1988).
- Managing heavily invaded areas poses a greater problem (Goodland *et al.* 1998). It is important to understand the structure and ecology of the vegetation community invaded. Large infestations may need to be removed slowly over time to allow the native plant community to regenerate and resume its role in the ecosystem.

  Where a dense native overstorey has been gradually replaced by woody weeds, the subsequent removal of the weed infestation can create large gaps in the canopy that may be detrimental to surviving native plants. Opening up the canopy favours the establishment of exotic grasses and other weeds and allows intense light to reach the shade-adapted native understorey. In contrast, removing weed trees from open woodlands, shrublands, herblands or grasslands, returns the *status quo* in terms of vegetation structure and sunlight intensity.

  Established woody weeds may be stabilising susceptible areas, especially along watercourses and on steep embankments. Removal of more than a few individuals at a time may result in severe erosion.
- Until the infestation is removed, there will be continued spread of propagules within the area and seedlings need to be removed as they appear.

Always plan to **follow up** treatments for several years to provide the greatest chance of eradicating the weed from an area. The few survivors or missed plants will quickly re-establish the infestation if left for a number of years.

Physical control – without herbicide

Manual and mechanical techniques such as pulling, cutting, stripping and ring-barking, may be useful to control some woody weeds, particularly if the population is relatively small.

Note: *Chainsaws should not be used unless operators are certified and supervised.*

Hand-weeding

Labour intensive but effective, hand-weeding is suitable for removing some light infestations of some weed seedlings and small saplings. However, the use of machinery or a large, inexperienced labour force can cause extensive soil disturbance and vegetation trampling.

- **Seedlings and small shrubs** can be carefully pulled by hand, ensuring removal of the taproot. Seedlings can be distinguished by the presence of a long taproot while suckers have a hockey stick shaped end, where they have broken off the parent root.
- **Saplings and mature trees** should not be removed using this method. The disturbance of soil structure and damage to native vegetation is counter-productive and may lead to invasion by other weeds. In addition, such disturbance of suckering species may stimulate growth from root fragments left in the soil.
- **Integration of hand-weeding with other techniques** is often appropriate. Removal of large trees by felling or herbicide treatment may be followed up by hand-removal of the flush of seedlings that are likely to appear.

Felling and ring-barking

These two techniques are suitable for trees and shrubs that do not resprout. The methods are labour intensive and may not be suitable for large infestations. Ring-barking is fiddley and the felling approach requires removal of branches from the site. However, on small infestations both techniques provide a simple, target-specific, control option.

Ring-barking involves cutting away a strip of bark, usually at least 10 cm wide, all the way around the trunk. The strip must be cut deep enough to stop the flow of photosynthates (plant food) between the growing points of the tree. To be successful, the phloem and vascular cambium (Box 6.2) must be completely severed around the circumference of the tree. Felling the tree at the base has effectively the same result, cutting the flow of food between roots and crown.

- **Seedlings** can be quickly slashed at ground level if not growing closely among native vegetation.
- **Non-sprouting shrubs, saplings and mature trees** can be cut off at, or very near, ground level below any branches or dormant buds. Many basically non-sprouting plants have epicormic buds higher up the trunk so it is important to cut off the trunk as close to the ground as possible.
- Keep in mind that surrounding vegetation can be damaged when trees and large shrubs are felled, and as branches are carried out.

Chemical control

Although the introduction of chemicals into bushland should be minimised, herbicide treatment remains the most successful means of control for many woody species. There are some general rules of thumb when using chemicals to control woody weeds, but treatment effectiveness will vary across species and sites.

- Apply herbicides as selectively as possible to target weeds, minimising damage to the surrounding native vegetation.
- Regardless of the application method chosen, all herbicides should be applied when the target species is actively growing.
- Herbicides should not be applied when plants are stressed; either through drought, flooding, disease, insect damage or previous herbicide application.
- Effective control of many woody plants requires a systemic herbicide to be used (Box 6.2, Chapter 8).
- Herbicides are rarely 100 % effective and an integrated control program will nearly always give the best result. Use a combination of different herbicide application techniques, physical methods and regeneration/direct seeding programs.

Note: *Anyone applying herbicides should have appropriate training in the safe use and handling of relevant chemicals (Chapter 8).*

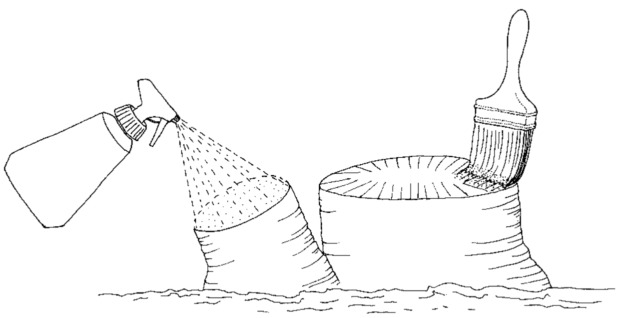
Foliar treatment

Treating the leaves or foliage of large trees with herbicide (foliar treatment) can be cumbersome and expensive. In addition, many tree species have thick, waxy leaf cuticles that make them highly resistant to spray. However, this approach can be useful for treating large, dense infestations of resprouting seedlings and small shrubs in degraded areas. Foliar treatment is not recommended for saplings and mature trees. It is impossible to spray the canopy of even a small tree within bushland without off-target damage.

Cut and paint

Cut and paint is a target-specific method, suitable for many small trees and shrubs that resprout. Successful control requires careful application – it is essential to apply the herbicide immediately to cut stumps. If delayed, the tree seals the wounded stump, preventing absorption of the herbicide. Large trees and shrubs may need to be cut down sequentially to avoid injury to workers and damage to the surrounding bush. Cut down the plant until one metre of trunk remains above the ground. With herbicide ready, cut the remaining trunk off close to ground level, apply herbicide immediately to the stump. The cut and paint method is labour intensive and can leave large gaps in the canopy. It is not viable for large infestations unless an experienced work crew is available and a consistent, systematic effort can be made over time.

- **Shrubs and small trees** can be treated by felling the plant close to ground level (5-15 cm) and immediately painting the exposed stump with a systemic herbicide. The entire surface of small stems can be painted using a paintbrush or sponge applicator. On larger stems, focus on the outer ring of wood containing the phloem, xylem and vascular cambium.



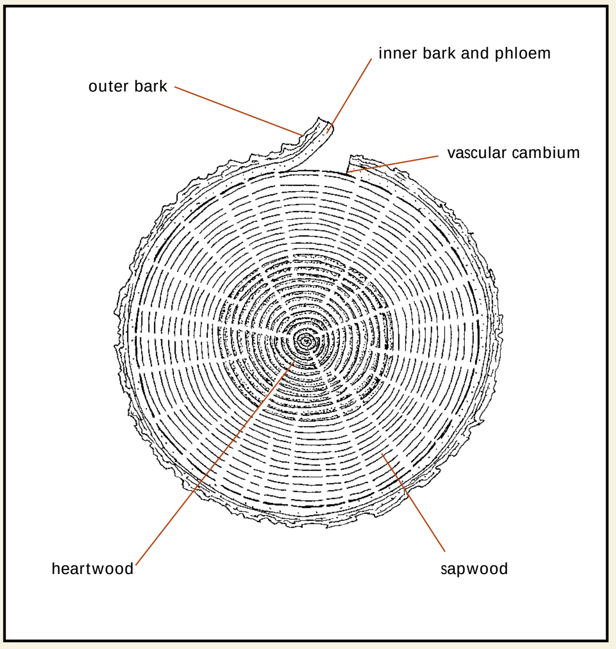
Box 6.2 Herbicide translocation in woody plants

Whether applied to the leaves, roots or stem of a tree, herbicide is transported around the plant within the xylem and phloem tissue. Understanding the function of these tissues and that of the vascular cambium is important in woody weed management.

Phloem is the tissue that is exposed when the outer bark is peeled away. These living cells are linked by protoplasm, forming an avenue for bi-directional movement of hormones and photosynthates between shoots and roots.

Vascular cambium describes the thin layer of cells with the ability to divide that lie beneath the phloem. Each year these cells produce a new layer of phloem toward the outside of the tree and a new layer of xylem, or wood, toward the inside.

Xylem consists of four kinds of cells. Tracheids and vessels, which at maturity are dead, are hollow cells responsible for the upward transport of water and dissolved solutes. Fibres provide structural strength and parenchyma cells, when living, provide a pathway for lateral movement across the xylem. While the parenchyma cells are alive, the xylem is physiologically active and considered part of the sapwood. When the parenchyma cells die, the xylem becomes heartwood; it provides structural support but no longer transports water and solutes. The sapwood can often, but not always, be distinguished by its lighter colour.



Cross-section of a tree trunk illustrating the location of outer bark, inner bark and phloem, vascular cambium and xylem (both sapwood and heartwood).

Uptake of herbicides in phloem

Herbicides with a molecular structure that allows them to cross living plant cell membranes may be carried in the phloem. They are called systemic herbicides and are readily taken into the phloem through leaves and roots. Phloem-mobile, systemic herbicides are not restricted to movement in the phloem however (Chaney 1985, Sindel 2000). Uptake directly into the phloem cells via trunk injection is unlikely; the cell contents are under positive pressure and when damaged, are forced out. Damaged cells are also quickly sealed with plugs of gelatinous material (Chaney 1985, Chaney no date).

Movement in the sapwood

All herbicides with some water solubility can be transported in the xylem (Sindel 2000). Within the xylem, continuous columns of water extend from the roots to the leaf cells. Unlike phloem cell content which is under positive pressure, liquid in the xylem is under negative pressure; as water evaporates from stomatal pores in the leaves, more is drawn upwards (Chaney 1985, Kozlowski and Pallardy 1997). Injected herbicide is initially pulled up into the tree due to this strong negative pressure. Once in the xylem, phloem-mobile herbicides can move across cell membranes making their way into the phloem to be transported around the plant (Chaney 1985, Sindel 2000). However, rapid application is vital. Trunk injection severs xylem cells, breaking the continuity of the water, introducing air and initiating wound healing - all processes that impede the uptake of injected substances (Chaney 1985).

Soil moisture, air temperature, and relative humidity affect the rate of water movement. For most temperate species, warm days with low relative humidity are associated with high transpiration. Injected substances are rapidly taken up. In contrast, when the temperature is cool or the relative humidity high, conditions that slow down transpiration, the rate of water uptake from the soil will be slow and trunk injection less effective. There are of course exceptions. Many Australian species, adapted to the hot dry climate, conserve water by not transpiring in the heat of the day during the summer months, and thus should not be injected at this time.

Felling **large trees** can result in damage to the native vegetation. Furthermore, the cut and paint approach may not deliver the quantity of herbicide required to kill the rootstock.

Removing branches from the site: Minimise damage to surrounding vegetation by planning your removal route in advance and cutting back large or bushy plants sequentially. Where possible avoid cutting down plants when they are covered in ripe fruit or seed, as carrying out the branches will help spread the weed! Never leave cut branches bearing seed or fruit in bushland – even unripe seed can ripen on cut branches. If possible put seed-bearing material into bags before carrying out of the bushland. Some plants, like Willow, Edible Fig and Poplar (*Populus* species) will also grow from branch cuttings. To avoid spreading such plants unwittingly, these species can be left standing and treated by stem injection or basal bark treatment.

Stem injection

As outlined in the section on apical control, plants may sucker primarily in response to canopy or root damage. Species which root sucker (including Silver Wattle, Lantana, Poplar and Brazilian Pepper) may be best treated by stem injection or basal bark methods (Box 6.3).

Stem injection techniques reduce herbicide damage to the surrounding environment. By placing the herbicide directly into the tree, contamination of soil and water, and damage to off-target plants is minimised. Response to stem injection will vary, depending on species, xylem anatomy, sap components, and environmental conditions (Box 6.2 & 6.4).

Box 6.3 Brazilian Pepper – a successful sucker

Brazilian, or Japanese Pepper (*Schinus terebinthifolius*), is a large shrub to small evergreen tree. Separate male and female plants produce small, cream flowers, but only the female tree produces the distinctive clusters of small red berries. The dark green leathery leaves emit a strong turpentine or peppery smell when crushed. Widely planted as an ornamental, Brazilian Pepper has successfully naturalised in more than 20 countries in two circum-global belts of roughly 15-30° North and South. The weed can form dense thickets, which shade out and smother native plants. Most invasive in moist situations, it also tolerates dry conditions and has been found growing and spreading on cliffs, roadsides and in bushland. Birds are the primary seed dispersal agents, although many mammals, gravity and water also play a part. Root suckers contribute greatly to local spread, especially after crown or root damage. In moist conditions branch cuttings will also take root (Anon. 1998, Elfers 1988a, Ferriter 1997, Parsons and Cuthbertson 2001, Randall and Marinelli 1996, Panetta and McKee 1997).

Successful strategies – some Brazilian Pepper biology

- Brazilian Pepper can reach reproductive age within three years of germination.
- Bears seed from April until October – an extensive period for seed dispersal.
- Seeds are dispersed by birds.
- Seedlings can grow in dense shade.
- Established trees are not usually killed by fire.
- Stems sprout prolifically after canopy damage.
- Suckering is enhanced by root or canopy damage.

Controlling Brazilian Pepper

Physical control

Seedlings: Carefully hand-weed being sure to remove all the root. Seedlings have a distinct tap root, suckers snap off leaving a hockey stick shaped end.

Saplings and mature trees: Do not fell as trees will coppice. Damage to the root system or canopy stimulates root suckering.

Chemical control

Saplings and mature trees:

Cut and paint: Does not allow sufficient herbicide to enter the system and cutting stimulates suckering. Only offers temporary control and the resultant resprouting, as much as 26 months later (Panetta and Anderson 2001), and root suckering forms denser thickets.

Stem injection/ basal bark: Correctly applied these techniques are preferable to the cut and paint method, resulting in a relatively high proportion of tree death and minimal suckering in the survivors.

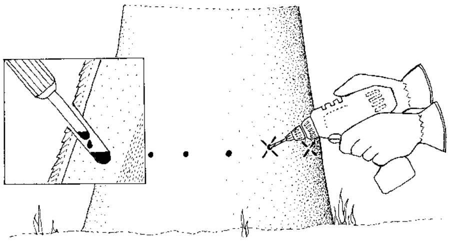
Resprouts: Foliar spray only if original trunk was small; if very large root stock, foliar spray over the proportionately small area of regrowth will not deliver enough herbicide to kill the plant. Instead, inject herbicide into the root crown.

Timing

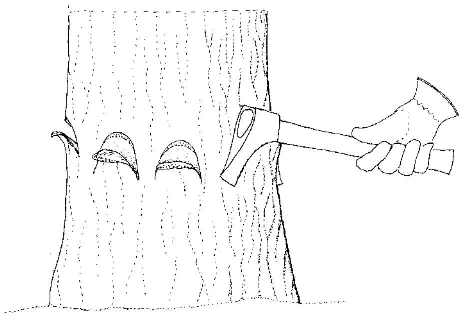
For maximum effect herbicide should be applied during summer when plants are actively growing and, in wet areas, where roots are not waterlogged.

Drill and fill: Holes 8-10 mm in diameter are drilled down at an angle into the sapwood around the base of the tree at 50-100 mm intervals, ensuring there is an injection point below each major branch. Inject approximately 5 mL of herbicide solution into the holes immediately after drilling each one. The hole depth will depend on the wood anatomy of the tree and thickness of the bark, but 30-50 mm is usually appropriate. A cordless drill or brace and bit can be used for drilling and the herbicide injected from a squirt bottle, large syringe or a drench gun. Alternatively, Sidewinder Tree Injectors® have been specifically designed for this task.

Note: *Common practice is to inject undiluted herbicide. While this is sometimes necessary, in other situations a 50 % or even 20 % solution is adequate.*

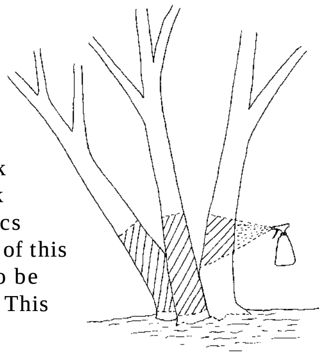


Frilling: Herbicide can also be injected into the sapwood by means of frilling. An axe is used to make cuts into the sapwood around the base of the tree. The cuts should be 30-50 mm wide by 20-30 mm deep (ensure cuts penetrate into the sapwood). Herbicide should be injected immediately into the cuts.



Basal bark

Basal bark treatment is useful on small stems – less than 20 cm in diameter and some larger trees with thin bark. The lower 60 cm of bark is painted or sprayed until dripping, with a herbicide and bark penetrant solution. The bark penetrant (usually diesel) carries the herbicide through thin bark and into the sapwood. Bark thickness and characteristics can influence effectiveness of this technique. Bark should also be dry and relatively dirt free. This method is quicker than injection or cut and paint, distributes the herbicide evenly around the tree base and thus evenly into the sapwood and is useful in tangled thickets.

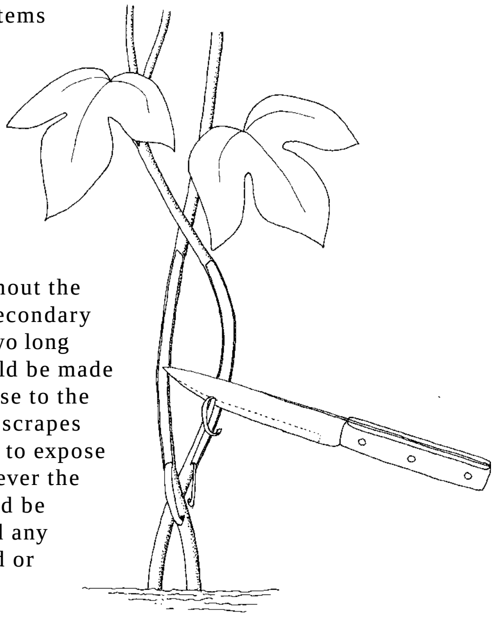


Treating climbers and brambles

Climbers present their own set of problems when it comes to control. They scramble over and through native vegetation making targeted spraying of foliage difficult. Climbers often have thin stems that cannot be injected, and when cut off at the base provide an inadequate surface area for herbicide uptake. They may also have the ability to sucker and/or stem layer, putting down roots from the stem into the ground and trunks or branches of other plants (Morning Glory (introduced *Ipomoea* spp), Japanese Honeysuckle (*Lonicera japonica*)). For these species, cutting off stems at the base only cuts one part of the nutrient supply and is ineffective. Many climbing species including Dolichos Pea (*Dipogon lignosus*), Morning Glory and Madeira Vine, have a large woody or tuberous root stock and techniques are required that introduce enough herbicide into the plant to kill it.

Scrape and paint

An effective way of killing climbers that sucker or stem layer, is to scrape the stems with a knife and immediately paint the exposed wood with a systemic herbicide. This method increases the surface area available for herbicide uptake and allows the herbicide to be translocated throughout the plant – including into secondary root systems. One or two long scrapes (300 mm) should be made along the same side close to the base of each stem. The scrapes should be deep enough to expose the sapwood, but not sever the stem. Treatments should be carefully monitored and any resprouts foliar sprayed or re-scraped and painted before they become entangled with native vegetation. The scrape and paint approach is suitable for Madeira Vine, which is particularly difficult to manage. It produces a multitude of both aerial and underground tubers which break off easily when the plant is disturbed and readily form new plants. With the scrape and paint method there is minimal disturbance to the canopy and aerial tubers will gradually wither and die on the plant (Muyt 2001). Remove and bag aerial tubers from the treatment area prior to scraping.



Box 6.4 Xylem anatomy and sapwood porosity

In plants, water and its dissolved solutes (including herbicide) are transported along the pathway of least resistance and this varies depending on the xylem anatomy. In cross section there are three main (and an array of intermediate) arrangements of vessels and tracheids within woody species: Non-porous, diffuse porous and ring porous (Chaney 1985, Kozlowski and Pallardy 1997).

Non-porous anatomy is found in gymnosperms, the conifers, which only have small, narrow tracheids for water uptake. Tracheids produced early in the growing season, the earlywood, have the largest diameters and are the main pathway for water transport. Three or four annual growth rings of xylem may be active (Kozlowski and Pallardy 1997).

Diffuse porous anatomy occurs in angiosperm trees, or hardwood species. Vessels, rather than tracheids are the primary water conductors. In diffuse porous woods, vessels of similar diameter are uniformly scattered in the early and latewood. The proportion of the sapwood conducting water varies between species, but commonly vessels found in the outer three or four growth rings are responsible.

Ring porous anatomy also occurs in angiosperms. However, here the vessels of the earlywood are larger in diameter than those of the latewood. It is these larger vessels of the current growth increment that conduct 99 % of the water and solutes (Zimmerman and Brown 1971, Chaney 1985, Kozlowski and Pallardy 1997).

The movement of sap upwards through the tree also varies between species. Sap may move in a continuous vertical path, from root to tip, although this is an exception not the rule (Zimmerman and Brown 1971). Depending on the arrangement of tracheids and vessels, sap may travel in spiral ascent turning right or left, interlocked ascent and sectorial straight ascent (Chaney 1985, Kozlowski and Pallardy 1997). Spiral ascent allows the most complete distribution of water from an individual root to many branches (Kubler 1991) and thus would distribute injected herbicide most widely.

Workers often report variable success rates using herbicide injection tecniques. Knowledge of anatomy and conduction pattern in the xylem helps tailor our injection technique, maximise its effectiveness and achieve consistent results. In non-porous and diffuse porous species, herbicide can be injected into the three or four annual growth rings below the bark. For ring porous species the injected material should be placed just beneath the bark in the current growth ring. The spacing of injection points can also influence treatment effectiveness. While there is usually some tangential spread of injected herbicides in the crown (Northcott 1957), trees with straight ascent pathways will often require more injection points than those with a spiral ascent pathway. If not, the result may be death of the tree in strips, resulting in some dead branches while others still live. This has been observed in the Flame Tree, *Erythrina* x *skysii* (Rod Randall pers. comm. 2001).

Foliar spray

Foliage provides a large surface area for uptake of herbicides. If the climber is growing over low shrubs, the bulk of the material can be pulled back off and away from native plants and sprayed. A good penetrant should always be used. This method is suitable for:

- Dense infestations where no native species are present and off-target damage will not occur.
- Small infestations in relatively good bushland where labour is available to carefully pull vines away from native plants.

Slash and spray

Infestations of plants such as Blackberry, which form thickets of stems up to two metres high can be difficult to treat. Larger, dense infestations in highly disturbed areas are better treated by leaving the plants intact and spraying with a systemic herbicide. Intact plants provide more leaf area, increasing the amount of herbicide that can be taken into the plant (Bruzzese and Lane 1996).

Foliar spraying small infestations of Blackberry among good bushland can result in off-target damage and accessing the root crown for injection is awkward. A number of community groups in the Perth region have found that slashing the plants, carting the bulk away and spraying regrowth once it is 50-100 cm high is effective. Blackberries will root readily from cuttings, so cut material must be removed from the site and disposed of carefully. Make sure plants are not cut down while in fruit as their removal from the bushland will spread the weed. Several follow-up treatments may be necessary.

Treating resprouts

No matter how good your technique, resprouting of trees, shrubs and climbers will occur in some species and/or under some conditions. Follow-up application of a systemic herbicide to foliage of resprouting plants and suckers is common practice. However, if the plant was very large and healthy prior to removal, the amount of chemical that can be applied to the foliage is likely to be insufficient to permanently damage the rootstock. Instead, try clearing away some soil and drilling holes around the base into the root crown. Fill the holes with herbicide as for the drill and fill technique.

If herbicide use is not desirable and the offending weed resprouts, try cutting the stump and then repeatedly cutting any regrowth. This should eventually exhaust the plant's reserves; but be prepared, it may take years! Alternatively, try stripping away all the bark from the stump to remove epicormic buds. This will not work for suckering species like Blackwood (*Acacia melanoxylon*), Flame Tree (*Erythrina* X *sykesii*), Tree-of-heaven or Eucalypts with lignotubers.

Seedling recruitment

The control of mature woody weeds usually frees light, space and nutrients, ideal conditions for seedling recruitment. Resources need to be made available to control any seedling flush. In some species seed is short-lived in the soil (Brazilian Pepper seed survives only six months) and follow-up control of seedlings is only required for a short period. For species with longer-lived seed, including many *Acacia* species, Broom (*Genista* spp) and Tagasaste (*Chamaecytisus palmensis*), follow-up may take a number of years. After the initial seedling flush is controlled, reduce further germination by encouraging the regeneration of native species. Keep out fire and other forms of disturbance until the soil weed seedbank disappears. In other situations it may be desirable to encourage weed seeds to germinate so they can be controlled and the soil seedbank exhausted.

Injection and basal bark herbicide treatments can induce seed drop in bradysporous species such as Cajeput (*Melaleuca quinquenervia*) (Coladonato 1992b). These are plants that retain most of their seed in the canopy. The herbicide places the tree under stress causing the canopy-stored seed to be released which may result in prolific seedling recruitment. Such species can be treated using the cut and paint method. Ensure no seed-bearing material is left in the bushland.

That said, canopy-stored seed is often only short-lived in the soil. Timing injection or basal bark treatments carefully can greatly reduce the amount of seed available for germination. For example, Sugar Gum (*Eucalyptus cladocalyx*) seed only remains viable in the soil for six months and the bulk of seed germinates in winter (Ruthrof 2001). By treating the plant in November, thereby inducing an early seed drop, most of the seed will lose viability over summer before seedling recruitment starts with the winter rainfall.

Even when follow-up control of seedlings is meticulously undertaken, seed can still be brought in from an external source and susceptible bushland should be monitored at least annually.

Making the most of unplanned fires

Fire is a source of disturbance and a major mechanism for spread and establishment of many woody weeds. Invasive Australian species (Acacias, Melaleucas, and Eucalypts), are often favoured by post-fire conditions. Many have large numbers of seeds whose germination is enhanced by fire. Others resprout or sucker, increasing the density of stands.

Nevertheless, for non-resprouting, non-suckering trees, particularly those with short to medium-lived seed, unplanned fire provides an opportunity for effective control. When mature plants have been killed or damaged by fire, follow-up treatment of seedlings by hand-weeding or spraying can greatly reduce the infestation.

- Fire can enhance germination of some seedbanks – resulting in mass germination and reducing the requirement for staggered spray programs. At Kings Park, Perth, mature plants of the resprouting Sugar Gum retain approximately 120,000 seeds in the canopy that are released to germinate *en masse* after fire (Ruthrof 2001). Post-fire control of resprouting adults and seedlings is very effective for this and other species with a similar fire response. Indeed, if seedlings aren't controlled then such species could rapidly dominate the bushland.
- Seedling recruitment can be extensive. Post-fire recruitment of *Acacia sophorae* has been recorded as high as 32,000 seedlings per hectare (McMahon *et al.* 1994). A consistent effort over a few years can drastically reduce, and sometimes eliminate the population.
- The fire itself may destroy a large portion of the weed seedbank. Intense fire has been shown to destroy a large proportion of the soil stored seed of Sydney Golden Wattle (*Acacia longifolia*) (McMahon *et al.* 1994), although less intense fires can result in mass recruitment.
- For some species such as Victorian Tea Tree (*Leptospermum laevigatum*) the season in which mature trees are burnt may be critical in determining the amount of post-fire recruitment of seedlings (Molnar *et al.* 1989).
- Whatever the scenario, funds must be available for post-fire control work or weed problems can be amplified. Other weeds, not just woody species, often have a more competitive advantage in fire disturbed communities, germinating first and smothering native species.

The question is then posed 'can fires be used as a tool to manage woody weeds?' There is little information regarding the use of fire as an actual management tool (McMahon *et al.* 1994). A review of the studies that have been done highlights a lack of common pre- and post-fire measurements (Downey 1999). Obviously a lot more research on weed and ecosystem response is required before fire can be recommended as a management tool. It is also important to appreciate the potential problems associated with using fire:

- Resources and commitment must be put into follow-up weed control or the problems will be exacerbated. Other weeds (especially grasses), not just woody species, often have a more competitive advantage in fire-disturbed communities, germinating early and smothering native species before they can establish.
- Even in fire-adapted plant communities frequent burns can result in loss of species diversity and changes in vegetation structure.

- Detailed research into the biology of the target weed, other weeds in the area and native species is often not available.
- Fires can easily get out of control damaging large tracts of bushland. In small remnants this may be disastrous for the native flora and fauna.

Woody weeds and waterways

Many south western Australian waterways are now inhabited by a range of woody weeds. Creeks provide favourable conditions for weed tree growth and act as a dispersal route along which propagules can float downstream. It follows that, when removing a large weed infestation from along a watercourse, you should always start your removal program at the top of the stream and move downwards. Weed control techniques themselves can contribute to the dispersal of propagules. Willows, for example, grow easily from cut pieces of branch left in the mud and can be carried to new sites by water. Therefore, it is important that all potential propagules are removed from the site.

When removing woody weeds from creeks and wetlands, the risk of erosion must be a primary consideration. Erosion can be started or compounded by the removal of woody weeds from embankments. Grubbing out the roots of mature trees causes major soil disturbance and stimulates erosion in most situations. Just leaving areas of bare soil allows water to move quickly across the surface and causes significant erosion problems. Entire removal of large areas of woody weeds should be very carefully considered. Even when removing small infestations, or part of a larger infestation, bare soil should be revegetated with local species as soon as possible. Rapid replacement of vegetation cover will minimise water run-off and thus loss of topsoil.

In Western Australia, if woody weeds are within 20 metres of flowing waterways or swamps, restrictions on herbicide use (Chapter 8) limit control choices. Felling, which does not use herbicide and does not cause major soil disturbance, is one option. But, for many suckering species this approach may lead to an increase in the weed infestation. Roundup Biactive® is registered in all states for use near waterways on some weeds and a minor use off-label permit (No. PER4984) approves its use in accordance with the label in aquatic situations in Western Australia. The highly targeted stem injection method, which contains herbicide within the tree, is a good option for use near waterways, especially if a non-residual herbicide is used.

Key points

Clearly the woody weeds as a group have much in common when it comes to management. The following summarises the key management issues and control techniques.

- Non-sprouting, non-suckering woody weeds can be felled. No herbicide is necessary.
- Species that resprout but **do not** sucker, can be treated by the cut and paint, stem injection, or basal bark methods.
- Species that sucker should be treated by stem injection or basal bark methods whenever possible.
- When using the stem injection method ensure there is an injection point below each major branch. On plants with multiple trunks each stem should be injected or sprayed. Trees should be injected when water uptake is at a maximum. Avoid stem injection during cold weather, flowering or drought.
- When applying the cut and paint or stem injection method, herbicide must be applied within seconds of tissue damage. Always use a systemic, or phloem-mobile, herbicide.
- Do not inadvertently spread the weed while removing branches.
- When removing infestations along waterways assess the possibilities of erosion, spread and chemical contamination first.
- Allocate resources for follow-up control of resprouts and germinating seedlings (after treatment and following unplanned fires).
- Knowledge of tree anatomy, physiology and biology allows you to tailor your herbicide application technique and management program.
- Fire can provide a major mechanism for the establishment of new populations of many species.
- Fire also offers a window of opportunity to greatly reduce and possibly eradicate populations.

Managing woody weed infestations is not straight forward. Depending on your reasoning, large populations could be removed slowly to minimise disturbance and allow time for bush regeneration, or removed *en masse* to prevent further spread of propagules. Indeed, 'large' depends on your perspective and the size of the area to be protected. Ideally, fruiting branches would never be taken out and the most suitable control method would be applied from the beginning. The following case studies describe how two community groups tackled their particular woody weed problem. They illustrate the need to gather as much information on the weedy plant as possible and highlight the 'reality' of woody weed control - the influence that residents, season and availability of labour have on the decisions made.

These case studies are followed by the woody weed management table ending the discussion of weed groups. The table presents information on the biology of individual woody weed species and known control methods. The final two chapters are dedicated to describing the simple, cheap and effective approach taken to weed mapping by EWAN staff throughout this project and discuss the frequently and less frequently asked questions about herbicide use in bushland.

Case study 6.1 Eastern Australian natives at Blue Gum Lake

The woody weed problem at Blue Gum Lake, Perth, is largely the result of misguided planting of eastern Australian natives. Sydney Golden Wattle (*Acacia longifolia*) and *Melaleuca linariifolia* (among others) were planted throughout the Swamp Banksia (*Banksia littoralis*) and Flooded Gum (*Eucalyptus rudis*) – Paperbark (*Melaleuca preissiana* and *Melaleuca rhaphiophylla*) woodlands during the 1980s and 90s. They have since seeded, quickly naturalising and spreading, particularly following fire. Their increasing presence alters plant community dynamics within this small urban remnant. Importantly, *M. linariifolia* was mistakenly planted as *Melaleuca preissiana*, a local species, highlighting the need to use locally collected seed from correctly identified species when planting in or near bushland.

The distribution of both weed species was mapped by overlaying a transparent map of the tracks on an aerial photograph and walking the bushland area. As there were local species superficially similar to the weed trees flagging tape was tied to each tree allowing quick, accurate recognition of weed species. The process took four hours to complete. It was low cost and provided a record of distribution so follow-up could be effectively carried out once all large trees were removed.

Management strategies differed for the two species reflecting basic differences in their biology:

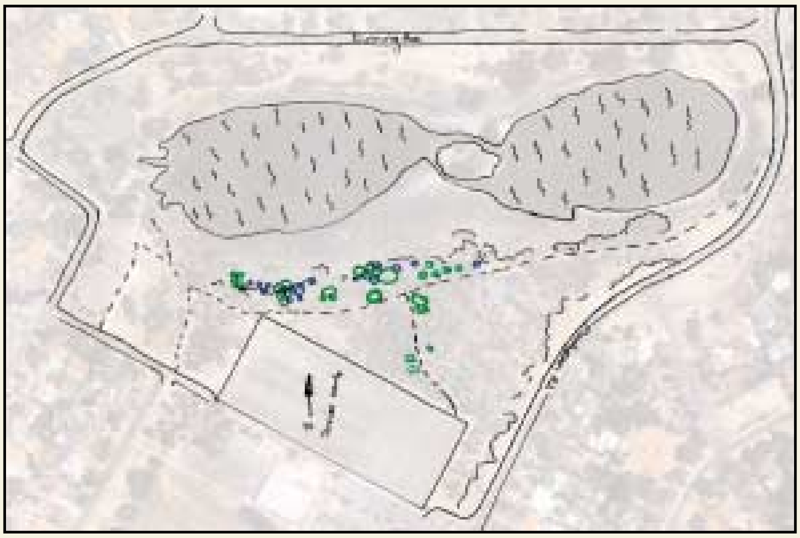
Acacia longifolia

Shrub to small tree
Does not resprout
Soil stored seed

Melaleuca linariifolia

Small to medium tree
Resprouts
Stores seed in canopy

Populations of both species were small and scattered, and removing them in a single effort was appropriate to prevent further spread and aid bush regeneration.



The distribution of Sydney Golden Wattle • and Melaleuca linariifolia *• at Blue Gum Lake, City of Melville, Western Australia.*

Acacia longifolia

A Bushcare work day was organised through the Department of Environmental Protection's Ecoplan program in July 1999. Volunteers assisted the Friends with the removal of 40 Sydney Golden Wattles. The trees were cut low to the ground with pruning saws and where necessary chainsaws. The branches were carried out of the bushland to be carted away by the local shire. To follow up the control effort, a Green Corps team and City of Melville Bushcare Officers took just a few hours to hand pull emergent seedlings.

The following August, flowering revealed a number of other mature plants hidden amid a dense stand of leggy Golden Wreath Wattle (*Acacia saligna*). These were removed with the help of two delightful Japanese volunteers who were not quite sure why we were taking out this beautiful 'native'. A thorough search of the area revealed lots of seedlings and a few more have been found and hand-pulled in the subsequent months.

The job is not over. Continued local government assistance and the input of time and effort from the Friends are important for continuity of the management program. Follow-up will need to be conducted annually for at least ten years; the soil seedbank of Sydney Golden Wattle is long-lived and trees reach seed bearing age in as little as two years. Resources should be made available for seedling removal if an unplanned fire occurs. Fire will enhance seed germination and the resulting seedling flush will largely exhaust the seedbank, providing an excellent control opportunity. The subsequent regeneration of the local Flooded Gum, and the Golden Wreath Wattle makes the effort worth while.

Melaleuca linariifolia

The removal of *M. linariifolia* posed additional problems. Several large trees grew within the bushland, a few close to the lake shore. The removal of these would be visible to residents across the lake. Therefore, the initial step was to convince the local council that residents would find the Swamp Banksia and Flooded Gum – Paperbark woodlands behind the weed trees equally as attractive. This took some doing. By removing the weed trees, and opening up the canopy there was also a concern that bare areas would be invaded by weeds.

Australian Trust for Conservation Volunteers (ATCV) assisted the Friends in the removal of the trees. The majority of the trees were large and bulky and a chainsaw was used

Sydney Golden Wattle growing in bushland at Blue Gum Lake .

Using a hand saw to fell a Sydney Golden Wattle at Blue Gum Lake.

to prune back each tree before cutting the stump low to the ground. Neat (100 %) glyphosate was immediately applied to the cut stump. To minimise damage to native vegetation, branch removal routes were carefully planned in advance for each tree. Care was taken to collect all seed-bearing branches, no matter how small, and remove them from the site. Large sections of trunk were left in the bush to rot.

In all, 20 trees were removed. It took eight people six hours to do the job. The following year saw a localised flush of *M. linariifolia* seedlings that were hand-pulled as they appeared and will continue to be removed until the soil seedbank is exhausted. Besides this flush of seedlings, the bare spaces were largely colonised by local species, specifically: Centella (*Centella asiatica*) and Pale Rush (*Juncus pallidus*).

Case study 6.2 Removing Edible Fig (*Ficus carica*) from Gingin Brook

In 1999 the Friends of Gingin Brook aquired funding to manage the bushland along a section of the brook. A major component was tackling various weed issues including a dense infestation of Edible Fig (*Ficus carica*), which was displacing the Flooded Gum (*Eucalyptus rudis*) and Swamp Paperbark (*Melaleuca rhaphiophylla*) woodland fringing the brook. Edible Fig is a resprouting, suckering species with fruit that ripen over summer. The Fig population was mapped and found to cover approximately two hectares. Isolated trees occurred elsewhere in the bushland area. The decision was made to remove the entire infestation over summer using the cut and paint technique. Although incongruent with many things said in this chapter, constraints of funding and access lay behind the decision:

Short-term funding and a Green Corps crew were available for work to be done at that time.

The Figs presented an impenetrable mass of branches that had to be cut out and removed in order to access the area for control of other invasive weeds such as Blackberry and Arum Lily.

The infested area was dry and access was better over summer. During winter and spring the area was mostly submerged.

By removing the entire population it was hoped to protect uninfested areas.

In the summer of 1998 the Green Corp team and the Friends cut down, painted stumps (with 100 % Roundup Biactive®) and carried out over 500 Edible Fig trees from the Flooded Gum and Swamp Paperbark woodland. In the two years since, there has been some germination, resprouting and suckering of Figs, the extent of which can only be estimated. Vigilant members of the Friends pull seedlings, spray foliage with 10 % Roundup Biactive® or drill and inject large root boles (100 % Roundup Biactive®) at any sign of growth. Lone trees which have since been found are treated using the drill and fill method (100 % Roundup Biactive®). This is the simplest method and appears to achieve a high proportion of deaths. In hindsight, to minimise spread, the group would have tried to avoid removing the Fig while in fruit. But again, access to the area limited the choices.

Removal of the Figs opened up the canopy and increased light became a factor. This resulted in an influx of annual and some perennial weeds including Bushy Starwort (*Symphyotrichum subulatum*), Rough Sowthistle (*Sonchus asper*), Glossy Nightshade (*Solanum americanum*) and Nutgrass (*Cyperus* species). With the hand-removal of these weeds by the Friends, the native plants Tassel Sedge (*Carex fascicularis*), Tall Sedge (*C. appressa*), Native Knotweed (*Persicaria decipiens*) and Waterbuttons (*Cotula coronopifolia*) are rapidly returning. Regeneration of the canopy species Swamp Paperbark and Flooded Gum has also been prolific.

	Common name	Dispersal agent	Seed storage and seedbank persistence	Years to first flowering	Vegetative regeneration strategy	Wood structure
Trees and Shrubs						
*Acacia baileyana**	Cootamundra Wattle	bird, mammal, ant	soil, long	2+	n (r)	
*Acacia dealbata**	Silver Wattle	bird, water	soil, long	5+	s,r,l	diffuse porous
*Acacia decurrens**	Early Black Wattle	water, bird	soil, long		r	
*Acacia elata**	Mountain Cedar Wattle				n	
*Acacia floribunda**	White Sallow Wattle	bird, ant	soil, long		s	
*Acacia iteaphylla**	Flinders Range Wattle	water, bird	soil, long	2	n	
*Acacia longifolia**	Sydney Golden Wattle	water, bird, ant	soil, long	2	n (r)	
*Acacia melanoxylon**	Blackwood	bird, water	soil, long	5	s,r	diffuse porous
*Acacia microbotrya**	Manna Wattle					
*Acacia podalyriifolia**	Queensland Silver Wattle	water, bird	soil, long		n	
*Acacia pycnantha**	Golden Wattle	water, bird	soil, long	3	r	
Ailanthus altissima	Tree-of-heaven	wind, water, bird		2+	s,r,l	ring porous
*Brachychiton populneus**	Kurrajong	bird, mammal	soil, short	8+?	r	diffuse porous
Buddleja dysophylla						
Buddleja madagascariensis	Butterfly Bush	bird (vegetative material)	no seed set recorded in Australia		r,l	ring porous/ diffuse porous
Callistemon spp* (not local spp)	Bottlebrush				r	
Callitris columellaris	Coastal Pine		short		s	non porous
*Casuarina cunninghamiana**	Sheoak	wind	canopy? soil, short	4+	n (r)	
*Casuarina glauca**	Sheoak	wind	canopy? soil, short	4+	s,r	
Chamaecytisus palmensis	Tagasaste	explosive	soil, long	3	r	
Chrysanthemoides monilifera	Bitou Bush	bird, water, mammal, ant	soil, medium/long	1.5	r,l	
Cotoneaster spp	Cotoneaster	bird	soil, short?	2	r	
Erica baccans	Berry Flower Heath	wind, water	soil, medium	3+	r	
Erythrina x sykesii	Flame Tree		no viable seed produced?		s,r,l	diffuse porous
*Eucalyptus botryoides**	Bangalay	wind	canopy? soil, short		r	diffuse porous
*Eucalyptus camaldulensis***	River Red Gum	wind	canopy? soil, short		r	diffuse porous
*Eucalyptus citriodora**	Lemon Scented Gum	wind	canopy? soil, short		r	diffuse porous
*Eucalyptus cladocalyx**	Sugar Gum	explosive, wind, water	canopy, soil, short		r	diffuse porous
*Eucalyptus conferruminata***	Bald Island Marlock	wind	canopy? soil, short		r	
*Eucalyptus globulus**	Tasmanian Bluegum	wind	canopy? soil, short		r	diffuse porous
*Eucalyptus maculata**	Spotted Gum	wind	canopy? soil, short		r	diffuse porous
*Eucalyptus muelleriana**	Yellow Stringybark	wind	canopy? soil, short		r	diffuse porous
*Eucalyptus polyanthemos**	Red Box	wind	canopy? soil, short		r	diffuse porous
*Eucalyptus saligna**	Sydney Bluegum	wind	canopy? soil, short		r	diffuse porous
Ficus carica	Edible Fig	bird, mammal	short?	4+	s,r,l	diffuse porous
Genista spp	Broom	explosive, bird, water	soil, long	2	r	
Gomphocarpus fruticosus	Narrowleaf Cottonbush	wind, water	soil,long	2	s,r	
*Hibiscus diversifolius**	Swamp Hibiscus		short	1	s,r	
*Lagunaria patersoniana**	Norfolk Island Hibiscus		short		n	

Eastern Australian natives naturalised in Western Australia. **Western Australian natives that have become weedy when planted outside their natural range.* ***Dispersal:* *mode of seed dispersal* ***Seedbank:*** *main storage of seed (canopy or soil), and length of seed viability, short = days to 1 year, medium = 1-5 years, long = 5 years plus.* ***Years to maturity:*** *years to first seed crop.* ***Regeneration strategy:*** *r = coppices/resprouts, l = stem layering, n = not sprouting or suckering, s = suckers (parentheses indicate occasional occurrence has been observed).* ***Management and control:*** *Injection = drill and fill or frilling*

Suggested method of management and control	References
Hand pull seedlings; fell mature plants, young plants may occasionally resprout. Basal bark - picloram/triclopyr.	58, 167, 231, 319, 51, 228, 242, 222
Hand pull seedlings; basal bark - picloram/triclopyr (autumn).	53, 58, 167, 319, 228, 242
Hand pull seedlings; basal bark - picloram/triclopyr (autumn); cut and paint - neat glyphosate.	53, 167, 231, 319, 228, 242
Hand pull seedlings; fell mature plants. Resprouting has been recorded in some areas - if in doubt basal bark spray with triclopyr/picloram.	58, 167, 242
Hand pull seedlings; try injection - 50 % glyphosate or basal bark - picloram +triclopyr.	167, 60, 242
Hand pull seedlings; fell mature plants.	58, 167, 242
Hand pull seedlings; fell mature plants, young plants may occasionally resprout. Basal bark - picloram/triclopyr.	53, 58, 167, 319, 228, 242
Hand pull seedlings; try injection - 50 % glyphosate **or** basal bark - picloram/triclopyr (autumn).	53, 58, 167, 319, 228, 242, 222
	167, 242
Hand pull seedlings; fell mature plants.	58, 167, 319, 242
Hand pull seedlings; basal bark - picloram/triclopyr (autumn); cut and paint - 100 % glyphosate **or** picloram/triclopyr.	53, 134, 319, 228, 242
injection 100 % glyphosate; basal bark - picloram/triclopyr (summer).	10, 30, 167, 248, 303, 320, 51, 242
Hand pull seedlings; try injection with 50-100 % glyphosate **or** basal bark - picloram/triclopyr; cut and paint - glyphosate.	48, 167, 242
Hand pull small plants - remove all stem material.	167, 242
Hand pull small plants - remove all stem material.	167, 241, 297, 242
Hand pull seedlings; try cut and paint with 50-100 % glyphosate.	167, 242
Try cut and paint with 100 % glyphosate; injection in this species with non porous wood may be ineffective.	124, 242
Hand pull seedlings;fell mature plants; cut and paint young plants - 50 % glyphosate.	167, 241, 291, 242
Hand pull seedlings; basal bark - Garlon®+oil; try drill and fill - 50 % glyphosate.	21, 114, 167, 241, 291, 242
Hand pull seedlings where possible; basal bark - picloram/triclopyr; foliar spray with 0.5 g/10 L metsulfuron methyl + Pulse®.	167, 231, 313, 228, 242
Hand pull small plants to 1m; cut and paint **or** inject 100 % glyphosate or foliar spray with 1 % glyphosate (spr-sum).	9, 21, 95, 167, 231, 248, 285, 327, 313, 2, 242
Seedlings difficult to hand pull; cut and paint with 40-100 % glyphosate **or** foliar spray - glyphosate + metsulfuron methyl (Trounce®) (spr-sum).	21, 167, 231, 51, 242
Digout small plants; cut and paint - 20 % glyphosate (aut-win); slash prior to seed set, spray regrowth within year - 1 % glyphosate.	21, 231, 242
Injection - closely spaced holes/frills or try basal bark- picloram/triclopyr.	9, 167, 242
Hand pull seedlings; try cut and paint **or** inject root crown - 50 % glyphosate; foliar spray regrowth - 1.5 % glyphosate.	134, 167, 231, 319, 242
Hand pull seedlings; try cut and paint **or** inject root crown - 50 % glyphosate; foliar spray regrowth - 1.5 % glyphosate.	167, 242
Hand pull seedlings; try cut and paint **or** inject root crown - 50 % glyphosate; foliar spray regrowth - 1.5 % glyphosate.	167, 231, 242
Hand pull seedlings; try cut and paint **or** inject root crown - 50 % glyphosate; foliar spray regrowth - 1.5 % glyphosate.	167, 231, 282, 242
Hand pull seedlings; try cut and paint **or** inject root crown - 50 % glyphosate; foliar spray regrowth - 1.5 % glyphosate.	167, 242
Hand pull seedlings; try cut and paint **or** inject root crown - 50 % glyphosate; foliar spray regrowth - 1.5 % glyphosate.	167, 231, 242
Hand pull seedlings; try cut and paint **or** inject root crown - 50 % glyphosate; foliar spray regrowth - 1.5 % glyphosate.	167, 242
Hand pull seedlings; try cut and paint **or** inject root crown - 50 % glyphosate; foliar spray regrowth - 1.5 % glyphosate.	167, 242
Hand pull seedlings; try cut and paint **or** inject root crown - 50 % glyphosate; foliar spray regrowth - 1.5 % glyphosate.	167, 242
Hand pull seedlings; try cut and paint or inject root crown - 50 % glyphosate; foliar spray regrowth - 1.5 % glyphosate.	167, 242
Hand pull seedlings; inject with 50-100 % glyphosate (summer); foliar spray regrowth with 10 % glyphosate **or** inject root boles.	167, 242
Hand pull small seedlings; cut and paint - 100 % glyphosate **or** foliar spray - 1 % glyphosate, repeat treatment (win-spr).	53, 134, 163, 231, 248, 344, 242
Hand pull small plants; foliar spray with 1.5 % glyphosate **or** try cut and paint - 50 % glyphosate (Sep-Dec).	248, 242
	124, 242
Hand pull seedlings; fell mature plants.	167, 242

 Trees, Shrubs and Climbers Weed Management Table

	Common name	Dispersal agent	Seed storage and seedbank persistence	Years to first flowering	Vegetative regeneration strategy	Wood structure
Lantana camara	Lantana	bird, mammal, water		2+	s,r,l	
Lavandula stoechas	Lavender				r	
Leonotis leonurus	Lion's Tail				s	
*Leptospermum laevigatum**	Victorian Tea Tree	wind	soil short, canopy	4	n (r) l	
Lycium ferocissimum	African Boxthorn	bird, mammal, water (skinks)	soil, short?	2	s,r,l	
*Melaleuca lanceolata***		wind, water	canopy, long/soil, short		r	
*Melaleuca linariifolia**		wind, water	canopy, long/soil,short		r	
*Melaleuca quinquenervia**	Cajeput	wind, water	canopy, long/soil, short	3	r (l)	
*Melia azedarach***	Cape Lilac	bird, water	soil, short/medium	3?	s,r,l	semi ring porous
Nicotiana glauca	Tobacco Tree	wind, water	soil, ?	1	s,r,l	
Olea europea	Olive	bird, mammal	soil, long	5+	s,r	diffuse porous
Pinus pinaster	Maritime Pine	wind	canopy, medium	7	n (r)	non porous
Pinus radiata	Radiata Pine	wind	canopy, medium	5+	n (r)	non porous
*Pittosporum undulatum**	Sweet Pittosporum	bird, mammal	soil, short/medium	5	r	diffuse porous
Polygala myrtifolia	Butterfly Bush	bird, ant, water	soil, short/medium	3	n	
Populus alba	White Poplar	wind, water	none? short?		s,r,l	diffuse porous
Populus nigra	Lombardy Poplar		no viable seed produced?		s,r,l	diffuse porous
Psoralea pinnata	Taylorina	bird, mammal, water	soil, long (8)	-1	(r)	
Rhamnus alaternus	Buckthorn	bird, mammal	soil, long	2?	r	
Ricinus communis	Castor Oil Plant	water, mammal, explosive	soil, medium	1+	r	
Robinia pseudoacacia	Black Locust	?	seedlings rare	6+	s,r	ring porous
Rosa laevigata	Cherokee Rose	bird, mammal	soil, medium	3	s,r,l	
Rubus spp	Blackberry	bird, mammal, water	soil, short	2	s,r,l	
Salix babylonica	Willow	wind, water	short (no female trees in W.A?)	4+	s,r,l	diffuse porous
Schinus terebinthifolius	Brazilian Pepper	bird, water	short	3	s,r	
*Solanum aviculare**	Kangaroo Apple	bird, mammal	soil, long	2+	s,r	
Solanum laciniatum	Kangaroo Apple				s,r	
Tamarix spp	Athel Pine, Tamarisk	wind, bird, mammal	short	3	s,r	ring porous
Ulmus procera	English Elm		fruit usually sterile		s	
Washingtonia filifera	Cotton Palm	mammal, bird	soil, short/medium	9+	n	
Vines						
Anredera cordifolia	Madeira Vine	water	aerial & underground tubers	na	r	
Asparagus asparagoides	Bridal Creeper	See chapter 4 - Corms, Bulbs and Tubers				
Cardiospermum grandiflorum	Large Balloon Creeper	water, wind	soil, short		r	
Dipogon lignosus	Dolichos Pea	explosive, bird, water	soil, medium	2+	r	
Ipomoea carica	Morning Glory	wind, water			r,l	
Ipomoea indica	Purple Morning Glory	water (stolons)			r,l	
Lonicera japonica	Japanese Honeysuckle	bird, mammal, water			s,r,l	
Parthenocissus quinquefolia	Virginia Creeper	ant, bird	soil, short-medium		r,l	
Senecio tamoides	Canary Creeper	wind, water			s	

Eastern Australian natives naturalised in Western Australia. **Western Australian natives that have become weedy when planted outside their natural range. **Dispersal: mode of seed dispersal **Seedbank:** main storage of seed (canopy or soil), and length of seed viability, short = days to 1 year, medium = 1-5 years, long = 5 years plus. **Years to maturity:** years to first seed crop. **Regeneration strategy:** r = coppices/resprouts, l = stem layering, n = not sprouting or suckering, s = suckers (parentheses indicate occasional occurrence has been observed). **Management and control:** Injection = drill and fill or frilling*

Suggested method of management and control	References
Basal bark- triclopyr/picloram (sum-aut) **or** cut stump; foliar spray regrowth with 1.5 % glyphosate; biological control.	29, 95, 231, 248, 295, 301, 242
Hand pull small plants; try cut and paint with 50 % glyphosate.	242
Handpull seedlings or small plants.	328, 242
Hand pull seedlings; fell mature plants. Resprouting has been recorded in some areas - if in doubt basal bark spray with triclopyr+picloram.	50, 123, 218, 319, 228, 191, 242
Injection - neat glyphosate; or basal bark with triclopyr/picloram (Feb-May); foliar spray regrowth with 10 % glyphosate **or** 1 % Grazon® + Pulse®.	95, 231, 248, 313, 342, 228, 242, 222
Hand pull seedlings; cut and paint - 50 % glyphosate.	242
Hand pull seedlings; cut and paint - 50 % glyphosate.	242
Hand pull seedlings; cut and paint - 100 % glyphosate (basal bark ineffective).	29, 75, 241, 302, 242
Hand pull seedlings; injection - neat glyphosate; basal bark - 10 % triclopyr (summer).	20, 241, 319, 242
	167, 319, 242
Hand pull seedlings; basal bark - triclopyr or try injecting into root crown - glyphosate (sum-aut); foliar spray regrowth - 1.5 % glyphosate.	7, 4, 231, 248, 242
Hand pull seedlings; fell mature plants; cut and paint young plants - try 50 % glyphosate.	21, 167, 231, 319, 242
Hand pull seedlings; fell mature plants; cut and paint young plants - try 50 % glyphosate.	21, 82, 167, 231, 319, 313, 242
Hand pull seedlings; cut and paint, injection - 50 % glyphosate (young plants killed by fire/slashing).	29, 134, 135, 167, 231, 279, 278, 142, 242, 230b
Hand pull seedlings - dense stands can be sprayed with 1.5 % glyphosate; fell mature plants.	21, 167, 231, 228, 242
Basal bark - 25 % triclopyr; injection - 70 % glyphosate; foliar spray regrowth.	81, 167, 272, 51, 242
Basal bark - 25 % triclopyr; injection - 70 % glyphosate; foliar spray regrowth.	81, 167, 51, 242
Hand pull seedlings (slash dense clumps); hand pull young plants 1- 2 years old, cut and paint - 20 % glyphosate **or** foliar spray 1 g/10 L metsulfuron methyl + Pulse®; fell mature plants.	21, 134, 167, 231, 228, 242
Hand pull seedlings; cut and paint - neat glyphosate; injection - Grazon®; foliar spray regrowth - 1.5 % glyphosate (autumn).	21, 79, 167, 231, 242
Hand pull seedlings; cut or scrape and paint - 50 % glyphosate; basal bark - triclopyr **or** Garlon® (spr-sum).	9, 95, 134, 167, 231, 242
Hand pull seedlings; basal bark - picloram/triclopyr (spr-sum): Intolerant of shade.	80, 167, 299, 304, 14, 242
Hand pull seedlings; basal bark - triclopyr (Dec).	167, 231, 248, 242
Hand pull small plants; cut and paint or slash canes and spray regrowth at 0.5 metres with metsulfuron methyl 1 g/10 L (sum-aut). Will require follow up for a number of years.	3, 21, 95, 167, 231, 241, 248, 47, 51, 343, 228, 242
Hand pull seedlings; injection - 50 % glyphosate (check restrictions on chemical use near waterways) (sum-aut).	4, 21, 167, 231, 319, 181, 242, 269
Hand pull seedlings; injection - 50 % glyphosate; basal bark - triclopyr/picloram. (summer).	76, 113, 167, 125, 167, 231, 245, 246, 248, 242, 39
Hand pull small plants; injection - 50 % glyphosate (sum-aut); basal bark with 1.5 % triclopyr/picloram.	167, 228, 242
Hand pull small plants; injection - 50 % glyphosate (sum-aut); basal bark with 1.5 % triclopyr/picloram.	167, 228, 242
Injection into root crown - neat glyphosate; cut and paint - 30 % triclopyr; basal bark or spray regrowth (autumn).	167, 215, 232, 248, 306, 242
Try injection with 50 % glyphosate **or** basal bark spray - picloram/triclopyr.	324, 242
Hand pull seedlings; chop off at base when not in fruit.	164, 167, 242
	242
Stem scrape or drill and fill thick vines - 100 % glyphosate (Do not cut the stem); intensive follow up of resprouts at 2-4 leaf stage.	9, 21, 167, 231, 242
	242
Hand pull small plants; sever stems, scrape and paint - 100 % glyphosate **or** foliar spray - glyphosate 1.5 %.	9, 167, 231, 242
Hand pull small plants ensuring removal of all root material; scrape and paint - 100 % glyphosate **or** foliar spray in highly degraded sites with 1.5 % glyphosate.	21, 167, 231, 228, 242, 233
Hand pull seedlings; scrape and paint stem - 20 -100 % glyphosate.	9, 21, 167, 231, 241, 242
Scrape and paint stem- 20-50 % glyphosate.	9, 21, 167, 231, 241, 242
Hand pull seedlings; scrape and paint stems - 100 % glyphosate; spray regrowth 1.5 % glyphosate.	9, 21, 74, 238, 241, 320, 51, 340, 242
Hand pull seedlings; scrape and paint stems - 100 % glyphosate; spray regrowth 1.5 % glyphosate.	73, 319, 242
Try 1 % glyphosate or Lontrel® 20 mL/ 10 L + wetting agent.	328, 242, 222

Chapter 7 Weed Mapping in Remnant Bushland

Mapping of individual weed species is an important step in setting priorities for weed control work in small reserves. Throughout the course of the project, EWAN has often been asked to participate in workshops, informing people on how to map weeds in bushland. To facilitate this process some mapping guidelines were drafted. This chapter is a revision of those guidelines and is designed to provide a step by step guide to weed mapping in urban bushland.

Equipment required

Aerial photograph of bushland

Aerial photographs are easily obtained from the Department of Land Administration (DOLA). It is important to know the date the photograph was taken and the scale of the photograph.

When weed mapping, it is practical to enlarge the image of the bushland reserve to A4 so it can be used with a standard clipboard. An aerial photograph of the 21 hectare Shenton Bushland fits onto an A4 sheet at a scale of 1:16000, while Talbot Road Bushland (60 hectares) fits at a scale of 1:60000. However, fitting a reserve larger than Talbot Road Bushland to an A4 sheet would result in loss of detail making it difficult to accurately map weed distribution.

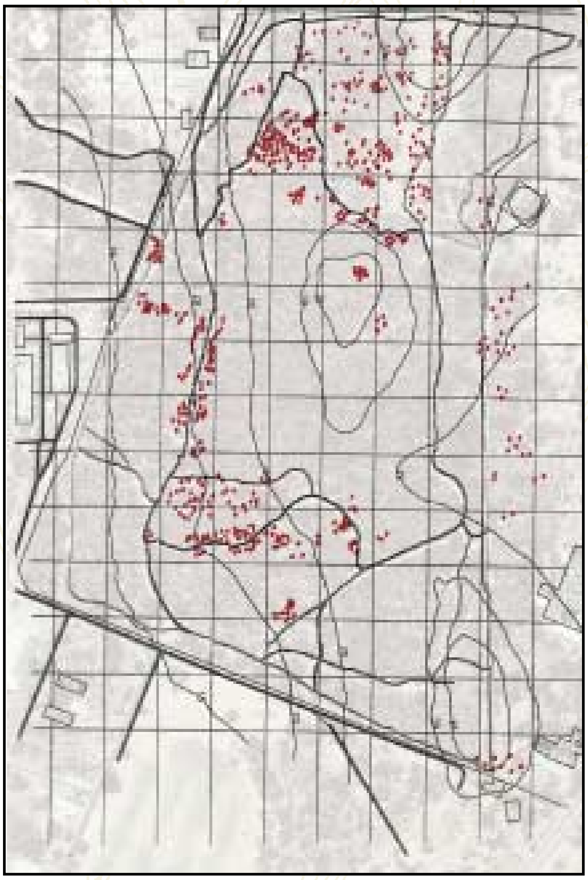


Figure 1. A map of Shenton Bushland was photocopied onto a clear overlay and adjusted to fit the aerial photograph. The distribution of Freesia • across the bushland was then mapped.

Map of bushland tracks

Sometimes the major tracks and features of a reserve have been mapped as part of a management plan. This map can be photocopied onto a clear overlay and the size adjusted to fit the aerial photo (Figure 1). Tracks and other features marked on the overlay provide reference points in the bushland.

Other Items

Clip board
Waterproof, permanent marking pens (medium tip)
Compass (can be useful)

What weeds to map?

It is not necessary to map all the weeds in a bushland patch. Some weeds may have very little impact on the native plant communities (Box 7.1). In Banksia woodland, many annual herbs and grasses fall into this category e.g. *Ursinia anthemoides, Aira caryophyllaceus*. Start by mapping five or six of the most serious perennial weeds. To determine these:

Consider site-specific issues. Which weeds are moving into, or have the potential to move into, undisturbed bushland? What impact does a particular weed have on the native plant communities?

Consult existing management plans (if available) and look at the weeds listed in the Environmental Weeds Strategy for Western Australia (Department of Conservation and Land Management 1999).

Visit the site throughout the year to determine what and where the serious weeds are. At Blue Gum Lake bushland, Paspalum (*Paspalum urvillei*) and Sydney Golden Wattle (*Acacia longifolia*) are the most obvious weeds over summer. In late autumn Soursob (*Oxalis pes-caprae*) and Annual and Perennial Veldgrass (*Ehrharta longiflora, E. calycina*) start to dominate. By winter, Freesia (*Freesia alba* x *leichtlinii*) and Yellow Soldier (*Lachenalia reflexa*) are obvious, often in undisturbed areas.

Box 7.1 Criteria used in the Environmental Weeds Strategy for Western Australia to assess weeds in terms of their impact on biodiversity

Invasiveness: Ability to invade bushland in good to excellent condition or ability of weeds to invade waterways.

Distribution: Current or potential distribution including consideration of known history of wide-spread distribution elsewhere in the world.

Environmental impact: Ability to change the structure, composition and function of an ecosystem. In particular an ability to form a monoculture in a vegetation community.

Source: Department of Conservation and Land Management (1999)

Mapping in practice

It is simplest to map one weed at a time. If a small group of people are present, colour photocopies of the aerial photograph can be provided so that each person can map a different weed. Before mapping begins, place a label on the bottom corner of the overlay and write the date, the name of the weed being mapped and those people participating in the mapping exercise. The date is essential if the map is to be used as a monitoring tool.

Traversing the bushland

Start at one edge of the bushland and walk across the site at regular, parallel, intervals. The intervals can be around 10 to 50 metres apart depending on the vegetation type and the visibility of the weed. A compass may be helpful. If the site is disected by paths, mapping within the sections of bushland created, can be more accurate.

Marking weed populations on the map

Many weeds occur in discrete clumps. Mark the location and spread (using the map scale as a guide to size) of the weed population on the map. Features on the overlay and aerial photograph (tracks, water bodies, vegetation boundaries, isolated trees and the roofs of houses adjacent to bushland) can be used to pinpoint the location of weed populations. Most serious weeds can be mapped in this way including bulbous, cormous and tuberous species like Watsonia (*Watsonia meriana*), Arum Lily (*Zantedeschia aethiopica*), Bridal Creeper (*Asparagus asparagoides*) and Freesia, woody weeds including weedy Acacias and Blackberry (*Rubus fruticosus*) and some grass weeds like African Lovegrass (*Eragrostis curvula*).

Mapping cover

Weed cover can also be mapped. Changes in cover over time can provide information on the success of a control program, increase or decrease in weed numbers or vigour and can give an indication of where to start control works. To map cover, different symbols or different colors can be used to represent cover classes. For example:

Light infestation 1-10 % of ground cover (green)
Light-medium 11-30 % (blue)
Medium-heavy 31-70 % (orange)
Heavy >70 % (red)

Mapping weed cover can be subjective but is often the only practical method of recording weed species that are spread throughout bushland in varying densities such as Perennial Veldgrass (*Ehrharta calycina*). Kings Park developed a system for mapping Veldgrass by estimating cover within a series of 50 m grids across the bushland (Bob Dixon unpublished data). This method was used at Blue Gum Lake (case study 3.4) and at Shenton Bushland (Box 7.3). The usefulness and practicalities of mapping weeds in this way will depend on the size of your reserve and the patchiness of the weed's distribution.

Weed mapping along creeks and waterways

It can be difficult to use aerial photographs to map along waterways as a dense overstorey of fringing vegetation often obscures recognisable features below. At Gingin Brook an aerial photograph was used to produce a scale mud map (Figure 2). The area along the brook was then walked and all the major weeds were mapped. The result is not as detailed as the maps mentioned previously but still helps in setting priorities and monitoring the success of control programs.

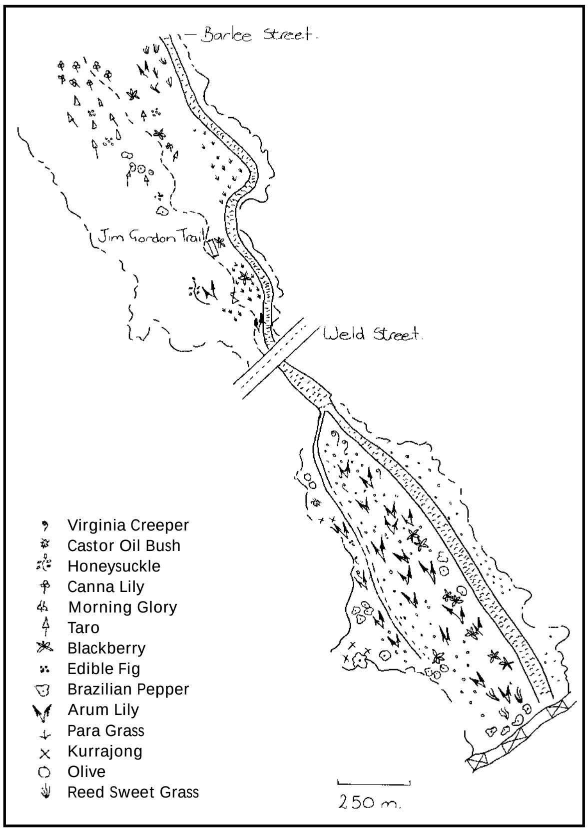


Figure 2. Mud map showing generalised distribution of weeds along Gingin Brook.

Using weed maps

Protecting the good bushland: Maps of individual weed species enable targeted control work and protection of priority areas from weed invasion. By overlaying maps of individual weed species onto a bushland condition map (Chapter 2, Box 2.1, Box 7.2) weed control strategies can be developed that aim to protect the least disturbed bushland. For example, small isolated patches of serious weeds in relatively undisturbed bushland can be identified and listed as a high priority for control.

Understanding the distribution of weeds in bushland: Overlaying weed maps onto vegetation maps can highlight relationships between weed species and particular plant communities. For example, Tribolium *(Tribolium uniolae)* distribution in the Brixton Street Wetlands is clearly associated with Marri woodlands and drier shrublands or the soil types these communities occupy. At Quairading Nature Reserve the distribution of the Wild Oat *(Avena barbata)* is clearly associated with the soils of the York Gum *(Eucalyptus loxophleba)* – Jam *(Acacia acuminata)* woodlands (Chapter 5, Box 5.2).

Monitoring the spread of established weeds and the effectiveness of control programs: Weed maps provide a useful tool for monitoring the establishment and spread of weeds. Mapping weed distribution and cover prior to beginning any control program and then in subsequent years will provide an indication of the program's effectiveness (Box 7.3). If no control is being undertaken then maps can provide general information on the rate of spread over time and whether or not a particular weed is moving away from disturbed areas into good bushland. Weed maps can also highlight the main direction of spread - along tracks, with prevailing winds or in sheet water flow.

Box 7.2 Vegetation condition maps

Vegetation condition maps illustrate how different degrees of disturbance are distributed throughout a particular bushland site and are a useful tool for developing management strategies. There are a two condition scales used in Western Australia (Kaesehagen 1994, Keighery 1994). Mapping of vegetation condition requires an understanding of the effects different types of disturbance may have on bushland, a knowledge of native flora and familiarity and understanding of what a particular undisturbed plant community would be like.

Table 1 Vegetation Condition Scale (Keighery 1994)

Vegetation Condition Scale

1 = 'Pristine'

Pristine or nearly so, no obvious signs of disturbance.

2 = Excellent

Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species.

For example, damage to trees caused by fire, the presence of non-aggressive weeds and occasional vehicle tracks.

3 = Very Good

Vegetation structure altered, obvious signs of disturbance.

For example, disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing.

4 = Good

Vegetation structure significantly altered by very obvious signs of multiple disturbance. Retains basic vegetation structure or the ability to regenerate it.

For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds, partial clearing, dieback and grazing.

5 = Degraded

Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management.

For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds, partial clearing, dieback and grazing.

6 = Completely Degraded

The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These areas are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.

Table 2. Bushland Condition Scale (Kaesehagen 1994)

Very Good - Excellent

- 80-100 % Native Flora Composition
- Vegetation structure intact or nearly so
- Cover /abundance of weeds less than 5%
- No or minimal signs of disturbance

Fair to Good

- 50-80 % Native Flora Composition
- Vegetation structure modified or nearly so
- Cover/abundance of weeds 5-20 % any number of individuals
- Minor signs of disturbance

Poor

- 20-50 % Native Flora Composition
- Vegetation structure completely modified
- Cover/abundance of weeds 20-60 % any number of individuals
- Disturbance incidence high

Very Poor

- 0-20 % Native Flora Composition
- Vegetation structure disappeared
- Cover/abundance of weeds 60-100 % any number of individuals
- Disturbance incidence very high

Box 7.3 Using maps to monitor change and set priorities at Shenton Bushland

Over the past four years a contractor has been employed to spray the Perennial Veldgrass (*Ehrharta calycina*) at Shenton Bushland. Perennial Veldgrass cover was mapped over the period using the method devised by Bob Dixon at Kings Park. Annual mapping provided a measure of effectiveness for the Perennial Veldgrass control program over time.

Perennial Veldgrass populations were mapped each May prior to spraying in winter. The maps reflected the success of the previous year's control program and were used for allocating the limited resources to priority areas in the current year. The project began with an $8000 grant to the Friends from the Lotteries commision in 1998. A fire had burnt through the central section of the bushland in October 1997. The Friends used the grant money to spray a 12 hectare section of unburnt bushland. By 1999 it became clear (with the help of maps) that the money should have been directed into the burnt areas. From 1999 onwards the Veldgrass populations were mapped each year and resources allocated accordingly.

1999 Resources available: $2000 grant to the Friends of Shenton Bushland from the Lotteries Commission, $6000 from Nedlands City Council. Directed to the central bushland area where dense infestations (in red) had established in good to excellent condition bushland following fire in October 1997.

2000 Resources available: $3500 Community Conservation Grant to the Friends and $6500 from the Nedlands City Council. The previous year's work in the good condition bushland was followed up, leaving the dense infestations around the edges of the bushland until more resources became available.

2001 Resources available: $6000 from Nedlands City Council. With Perennial Veldgrass now at less than 5 % cover over much of the bushland in good to excellent condition, resources were redirected to the degraded edges. The dense infestations in these areas were a fire hazard and a seed source capable of re-infesting the rest of the bushland.

2002 Resources available: $6000 from City of Nedlands and $7000 from Swan Catchment Urban Landcare Program. Perennial Veldgrass cover across much of the bushland down to around 5 %. Enough resources to do follow-up work across the bushland excluding the central area.

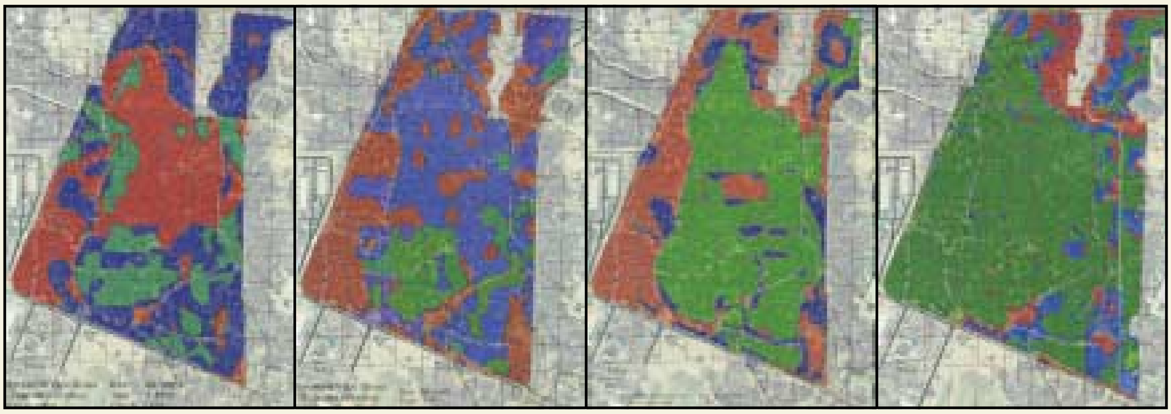


Figure 1. Maps illustrating the change in cover of Perennial Veldgrass at Shenton Bushland following a four year control program.

Setting priorities and developing works programs: Having an accurate picture of the distribution of the weeds at a bushland site can help set priorities and develop works programs (Box 7.3). The information generated allows satellite populations of weeds in good bushland to be targeted, highlights light infestations appropriate for hand-weeding and dense infestations that may require spraying. The maps provide information on proximity to waterways and may highlight potential problems for control such as contamination or erosion.

In conclusion

For those with the time, resources and inclination, the resultant maps can be digitised and the data placed into a digital geographical information system, or GIS. However, a small scale paper GIS, the traditional kind, consisting of aerial photograph and overlays of vegetation communities, tracks and features, bushland condition and weed distribution has proved more than adequate for making management decisions in Perth's urban bushlands.

Chapter 8 Herbicide Use in Bushland

The issue of herbicide use in bushland is sometimes a sensitive one. This chapter aims to give the reader a greater understanding of herbicides, their fate in the environment and the legislation regarding their use. It sometimes does this by directing the reader to alternate sources of information. The role of spray contractors in bushland regeneration is also discussed and some basic information given on the herbicides mentioned throughout this manual.

Using herbicides in bushland

Many professional bush regenerators and members of community groups are uncomfortable with the use of herbicides in bushland, others actively oppose it. Nevertheless, herbicide use in bushland management appears to have increased in recent times. Bush regenerators try to use herbicides only in very target-specific situations: The injection of herbicide into the trunk of trees, spot spraying individual grass clumps with selective herbicide or the wiping of leaf blades for cormous species like Watsonia. It is often a choice between the minimal damage done by carefully targeted herbicides and the loss of animal and plant biodiversity caused by dense invasions of weeds. When applied carefully by trained personnel with a detailed knowledge of herbicides and of the flora and bushland they are working in, herbicides can be an invaluable weed management tool:

- Herbicides can control more weeds more quickly and with less labour than appropriate physical methods.
- They cause fewer physical disturbances to the soil and surrounding vegetation - limiting erosion and reducing the creation of microsites for germination of other weed species.
- They avoid the carrying of weed material through good condition bushland, decreasing the dispersal of seeds and reproductive propagules.
- Grass-selective herbicides are available that cause little or no damage to species not of the grass (Poaceae) family.
- Broad-spectrum herbicides can be applied selectively to the target plant.

Duty of care

Before using herbicides in bushland, or employing someone else to use them for you, personal safety of the applicator and others in the area need to be considered.

People who use herbicides in bushland, including volunteers, have a 'duty of care' to the environment, members of the public and themselves. A clear, informative explanation of the section in the Occupational Safety and Health Act 1984 involving chemicals in the workplace and working with pesticides, is available online at http://www.safetyline.wa.gov.au/pagebin/hazshazd0018.htm. Briefly:

- Applicators (including volunteers) should have appropriate training in the safe storage, handling, preparation and use of any herbicide they use.
- Current Material Safety Data Sheets (MSDS) must be on hand and available for perusal by any persons coming in contact with the herbicide.
- The public should be made aware of any chance they may come into contact with a chemical.
- All hazardous substances kept on the premises should be named in a poisons register and the associated MSDS stored with them.
- Herbicides should be transported and stored safely.
- Herbicides must be labelled correctly. It is an offence to permanently store registered herbicides in anything other than their original containers with their original labels. Temporary containers must be labelled with the product name and the appropriate risk and safety phrases.
- Information and training should be provided to group members on potential health risks and toxic effects, control measures, correct use of control methods and correct care and use of personal protective equipment and clothing.

Personal care

The application of herbicides involves a high degree of personal care. Long-term effects of most herbicides are unknown and it is safest to avoid contamination. Herbicide labels carry a protective equipment list that identifies the minimum safety requirements. Protective equipment should be worn during:

- Mixing of herbicides.
- Application.
- Entering a treated area before the herbicide has dried or dissipated.
- Further steps that aid in personal hygiene are listed in Box 8.1.

In Australia a poisons schedule system is in place. The schedule number indicates the level of toxicity of the chemical to humans and the precautions that should be taken. The poisons schedule does not give an indication of danger to the environment. All pesticides, including herbicides, are classed as either S5, S6, S7 or exempt from scheduling, depending on their degree of hazard:

- Exempt from scheduling – pesticides that present little hazard in their use. Non-toxic.
- Schedule 5 (domestic poisons) – poisons that require caution in their handling, use and storage. Low toxicity.
- Schedule 6 (industrial poisons) – dangerous poisons available for agricultural and industrial application. Moderately toxic.
- Schedule 7 (special poisons) – substances of exceptional danger that require special precautions in their manufacture and use. Extremely toxic.

A comprehensive chart, detailing schedules for a wide range of herbicides and protective precautions that should be taken is available from the Kondinin Group (Ph: 9478 3343; web site www.kondinin.com.au).

Box 8.1 Personal safety and herbicide use

The long-term effects of a number of herbicides are unknown. Herbicides can be absorbed through the skin, by inhalation or swallowing. Personal protective equipment (PPE) can limit exposure through these routes. The minimum PPE that should be worn depends on the toxicity and concentration of the herbicide and the conditions in which it is used. Maintaining a hygiene level that avoids as much contamination as possible is sensible.

Clothing When handling concentrated chemicals during mixing, a PVC apron that reaches from shoulders to boots should be worn so that any spills can be quickly cleaned off. Always wear a long-sleeved shirt and long pants. Cotton, leather, canvas and other absorbent materials are not resistant to herbicides (even granular formulations) so the more layers of fabric the better. Wash work clothes separately from other laundry and air-dry outside. Wash hands after handling contaminated clothes.

Gloves Hands and forearms get the most exposure during spraying. Wear chemical-resistant gloves reaching up to the elbow and have sleeves tucked in. Butyl, nitrile or PVC gloves can be used. Make sure your gloves are clean and in good condition and replace them regularly. Always wash gloves before removing them.

Boots Wear chemical-resistant rubber boots that reach at least halfway to the knee. Try to avoid walking through sprayed areas. If possible wash footwear before removing.

Respiratory protection Dust/mist masks must fit and be used properly to be effective. Their use is most important in enclosed spaces or where the applicator is exposed to the chemical for long periods of time. Pesticides that can volatilise require the use of respirators. Check the label.

Eye protection Safety glasses and goggles should be worn, especially during mixing when concentrated herbicide is being handled. A full face shield will give the best protection.

Hygiene Be extremely careful during mixing. Exposure of the skin to concentrated herbicide during this short time can be the same as exposure from a full day working in the field. Wash hands before eating, drinking or smoking. Change clothing after spraying and wash hands, forearms and face with warm water and mild detergent. Shower at the end of the workday and wash your hair.

Regardless of the poisons schedule of the herbicide or the protective equipment being used, two items should be immediately on hand for emergencies when using herbicides: Eye wash and several litres of clean water.

Training

It is not the purpose of this manual to provide guidelines on the storage, transport, mixing and use of herbicides. Any person using herbicides in bushland should have undertaken appropriate training. Training should cover the safe handling and use of herbicides and the use and calibration of equipment.

- ChemCert WA runs a basic one day course on the safe use and handling of farm chemicals, including herbicides. Ph: 08 9341 5325
- The 'Certificate of Pest Control (commercial) Studying Pesticide Safety' is a more detailed course offered by correspondence through Challenger TAFE's WA Horticulture and Environmental Skills Centre. Ph: 08 9229 9513
- 'Pest Control Stage 1 Pesticide Safety' is a one week pesticide safety course available through the Australian Centre for Work Safety, Carlisle TAFE. Phone: 08 9267 7353

The last two courses fulfil the requirements to obtain a provisional pesticides applicators licence from the Pesticide Safety Section, Health Department of WA.

Applicators should also obtain a good working knowledge of the herbicides they use, who else uses them in their work area, and how the herbicides behave and move in the environment. Material Safety Data Sheets are available from the herbicide manufacturers and distributors and provide information on mode of action, toxicology of the chemical and its fate in the environment. Other sources of useful information include:

- Australian Weed Management Systems (Sindel 2000) which has two chapters that provide a good, if sometimes technical, overview of these topics.

    Chapter 11. Herbicide mode of action and herbicide resistance (Preston 2000).

    Chapter 12. Application and fate of herbicides in the environment (Kent and Preston 2000).

- Weed Control Methods Handbook (Tu *et al.* 2001). Chapters 5 to 7 provide information on safe use, mode of action and detailed information on the properties of several herbicides used in bushland.
- The Extension Toxicology Network provides unbiased, easy to understand information on a range of herbicide-related subjects from entry and fate of chemicals in humans to movement of pesticides in the environment. Their 'Toxicology Information Briefs' are available online at http://ace.orst.edu/info/extoxnet/tibs/ghindex.html

Legislation

In Western Australia, state and local government workers, consultants, contractors and volunteers who use herbicides are all bound by legislation governing pesticide use (The Health (Pesticides) Regulations 1956). These regulations are in place to protect the applicator, public and environment from the misuse of herbicide.

Herbicide labels: The first point of reference and most easily obtained legal document is the herbicide label. The user has a legal obligation to read and follow the instructions on the label. Directions of use, protection of environment, storage and disposal and personal protective equipment must be adhered to. This includes using herbicides only for the weeds, situations and states or territories permitted on the label. Herbicide treatments of many bushland weeds are not listed for use on the labels. In Western Australia the only herbicide registered specifically for use in bushland situations is Fusilade 212® on Perennial Veldgrass (*Ehrharta calycina*). For this reason it may be necessary to apply for an off-label permit.

Off-label permits: An off-label permit allows 'registered products to be used for a purpose or in a manner that is not included on the approved label'. Permits for off-label use of a registered herbicide can be obtained from the National Registration Authority (NRA). The Western Australian Department of Agriculture obtained a minor use off-label permit for a number of herbicides to be used specifically on environmental weeds in bushland. The permit (No. PER4984) is valid from 13 September 2001 to 30 September 2006 unless cancelled and is available online at http://permits.nra.gov.au/PER4984.PDF. Any person wishing to use a herbicide product and application method in a manner outlined on the permit must read the permit.

Licencing: Anyone applying herbicide for financial gain is required, by law, to be licenced with the Pesticide Safety Section, Health Department of Western Australia, and work for a registered company. This includes herbicide contractors and any bush regenerator who hires themselves out to community groups or government departments. Registration ensures that these people have undertaken appropriate training in the storage, preparation and use of herbicides. Contractors must also clearly display signs warning the public that herbicide is being used in the area.

Water catchments: According to the Health Department, six herbicides may be used in Water Catchment Areas (WCA) as defined by the Water Corporation of Western Australia. These are 2,4-D, amitrole, glyphosate, hexazinone, picloram and triclopyr. They may only be used when no other means is suitable for eradication of a weed and several restrictions apply. These include:

- Application is limited to injection or spot spraying with a large droplet spray.
- Herbicides cannot be mixed within 50 metres of reservoirs, rivers or streams.
- No application is to be made within 20 metres of reservoirs, rivers or streams except during summer months where these are dry.

The full details and definition of WCA are available in 'Circular PSC88 Use of Herbicides in Water Catchments' This document is available online at http://www.public.health.wa.gov.au/environ/applied/PSC88.DOC). The circular is dated 1993, and is currently undergoing revision by the relevant government departments.

In 1995, the Western Australian Department of Environmental Protection released a report on the acute toxicity of Roundup 360® to selected frog species (Bidwell and Gorrie 1995). Following the subsequent review of glyphosate use by the NRA, Monsanto introduced Roundup Biactive. This herbicide is registered for use in aquatic situations under certain conditions in all states of Australia. The minor use off-label permit PER4984 also allows the use of glyphosate in aquatic situations in accordance with label instructions.

Bushland care

Before applying herbicides it is essential to familiarise yourself with the site conditions. Compile a list including soil type, soil pH, proximity to open water, depth to groundwater, potential for run-off, occurrence of rare species (flora and fauna) etc. Base the decision to use herbicides on conservation targets for the site, potential behaviour of herbicides at the site in question, and the health and safety of applicators and others in the vicinity. Herbicides are poisons and should be used with caution.

Minimising damage

Following the label instructions does not mean off-target damage will not occur. The degree of off-target damage depends on the herbicide used, soil type and landform, weather, application method and skill of the operator. Several steps can be taken to minimise the risks of herbicide damage to the environment:

- Ask yourself if spraying is necessary (record reasons for choosing herbicide).
- A protocol for storing, mixing, transporting, handling spills and disposing of unused herbicides and containers should be in place before purchasing herbicides.
- Ensure that the person applying herbicide is trained in the safe storage, handling, preparation and use of the herbicide in question.
- The person applying herbicide should have a good understanding of the issues surrounding weed control in native bushland (the possibility of rare and endangered species, the effects of trampling, damage caused by over-spraying, importance of correct identification of target weed).
- Select a method that minimises off-target damage. Targeted techniques such as injection or wiping are most appropriate. If spraying is unavoidable use a large droplet spray to minimise drift. Use of in-line pressure regulators before the spray nozzle will help minimise droplet drift. Large-leafed plants like Arum Lily (*Zantedeschia aethiopica*) can have herbicide applied to individual leaves using a small, hand held, one litre garden sprayer. Hoods that direct herbicide onto the target plant are also available.

- Select herbicide and rate most effective at controlling the weed and with least damage to environment (selective, non-residual, low toxicity to humans and other organisms, lowest effective rate). Residual herbicides (metsulfuron methyl, picloram) can remain active in the soil for up two years, which can affect the growth of susceptible native plants over the period. Soil-mobile residuals could also contaminate waterways. However, for some weeds it may be more sensible to use a higher rate and/or a more toxic or more residual herbicide than an ineffective treatment that requires repeated application and does not remove the weed threat.
- Understand the hydrology of the system that is being treated. The likelihood of run-off into waterbodies and/or leaching into the water table must be assessed. If necessary, establish 'no spray' zones. Only use herbicides that have been specially formulated to have minimal impact on aquatic organisms. Don't add surfactants or wetting agents to such formulations as these are often more toxic to many aquatic organisms than the active ingredient in the herbicide. Use herbicides with low soil mobility where possible.
- Establish a mixing area (easy access, no desirable species, not subject to erosion or run-off, rarely visited by public or workers).
- Use a dye to minimise missed areas and avoid over-spraying.
- Always apply at the most appropriate time (ineffective application results in failure and unnecessary use of herbicide in bushland).
- Monitor effects of treatment on the whole plant community using a transect or quadrat-based approach which quantifies the number and cover of native plants. Native plant species include more than just trees and shrubs. Monitoring must include annual and perennial herbs, geophytes and grasses whose loss from the plant community should not be overlooked.
- Identify mistakes and if necessary improve your method. Monitor the effects of treatment on the weed quantitatively. Use the same transects or quadrats set up for monitoring the plant community. At the very least, keep a record of plants/area treated, the herbicides and rate used, date and conditions.
- Always follow up weed control work. If treatments are not followed up with further spraying or hand-weeding of overlooked or surviving plants, the initial treatment becomes a waste of resources and a pointless introduction of herbicide into the environment.

Using contractors

There is some concern about contractors entering the field with insufficient training in the application of herbicides within bushland situations. Contractors unsympathetic to bushland conservation are more likely to damage native plants through trampling, misidentification, or over-spraying. The contractor you select should have knowledge of the flora and an interest in bushland flora and fauna as well as an understanding of the chemicals used, the way they work and the weeds they control. They should be willing to use backpacks, hand held sprayers, or wiping devices when required. Such contractors are rare and in high demand throughout the peak weed season. At present, there are few suitable contractors available. The Australian Association of Bush Regenerators (Western Australia) (AABR (WA) Inc) has a list of those contractors in the Perth area that have sufficient experience to undertake bushland work. This list is available from AABR (WA) Inc., PO Box 1498, Subiaco, 6904. Ask around, get second opinions and if you are not happy with someone's work be sure to let them know why!

Make sure the spray contractor you hire and their employees have the appropriate training. Spray contractors must work for a business registered with the Pesticide Safety Section (PSS) of the Health Department of Western Australia (Ph: 08 9383 4244). A person with a provisional licence can carry out spraying as long as a person holding a full licence supervises them. Any person operating a pesticide spraying company must hold a full licence.

To get the most for your money and the best job done, it is important to have weed maps and a contract. The contract (Appendix 1) outlines the work to be done and ensures that if the job is not done satisfactorily you are in possession of a written agreement. The Weed maps are multi-purpose, they allow you to show the contractor the location of the weed populations; walk around the bushland with the contractor and relate populations to those on the map. By supplying the contractor with the weed map before the job, they are more easily able to relocate each population. The map also provides a monitoring tool that allows you to assess the reduction in population area and ensure no populations are overlooked by the contractor. In combination these two documents are invaluable (Box 8.2).

Some herbicides used in bushland

All applications and concentrations quoted in this manual are intended as an illustrative guide. They are covered by minor use off-label permit number PER4984, which is only valid for Western Australia.

Some useful herbicide terminology:

- Contact – kills only plant tissue to which it has been applied. Old or well-established annual plants may grow back after such treatments.
- Systemic herbicide – penetrates plant cells and moves through the plant from shoots to roots in the phloem.
- Broad spectrum – kills a wide range of plants.
- Selective – kills only a particular type of plant, e.g. grasses.
- Non-residual (knockdown) – kills existing plants but has no effect on subsequent germinants.
- Residual – remains active in soil for some time (may kill germinating seeds (pre-emergent) and susceptible plants).
- Post-emergent – applied directly to established plants and/or soil.
- Pre-emergent – applied to the soil before the weed germinates, killing germinating seedlings (pre-emergent herbicides will also kill susceptible native seedlings).

Box 8.2 Using contractors to spray African Lovegrass at Talbot Road Bushland

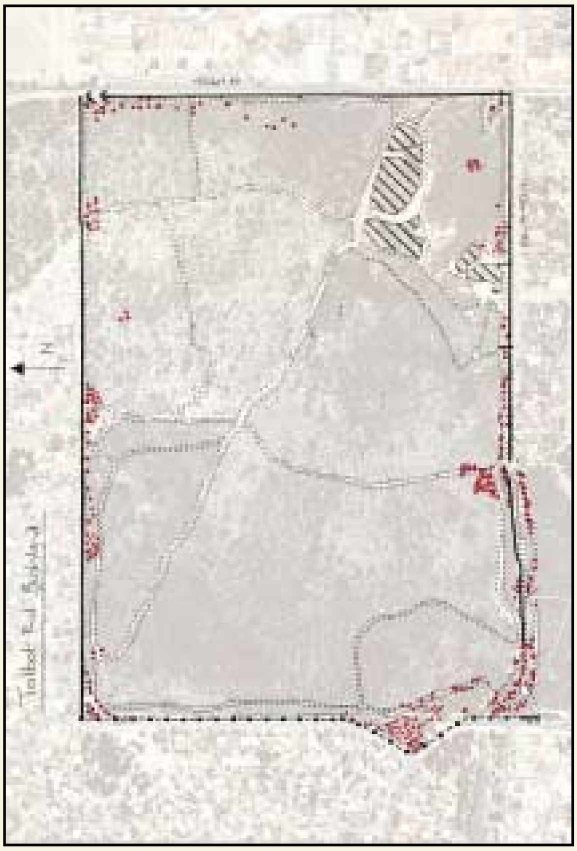
Between 1999 and 2001 infestations of African Lovegrass (*Eragrostis curvula*) at Talbot Road were mapped annually as part of the overall weed management strategy. The weed was found to be widespread on the tracks and bushland edges. In August 1999 contractors were employed to spot spray the infestations with a 1 % solution of glyphosate. The work was carried out when the African Lovegrass was actively growing and cost $1645.

A thorough examination of the site after spraying revealed that several populations of African Lovegrass had missed treatment altogether. In a number of other areas Perennial Veldgrass (*Ehrharta calycina*) had been mistaken for African Lovegrass. While glyphosate was appropriate to use on dense infestations of African Lovegrass growing along path edges, Perennial Veldgrass extended into the bushland and grew closely among native plants. Where Perennial Veldgrass clumps had been sprayed, off-target damage from the glyphosate was evident. If Perennial Veldgrass had been the target weed at this site a grass-selective herbicide would have been specified.

Although the contractors had originally been met on site and the job discussed in detail, no maps were supplied to them and no contract outlining the work had been signed. If a contract had been signed, both parties would have had a clear understanding of exactly what was required and a means of redress when those requirements were not met.

After discussions, the contractors returned to respray missed infestations. When the contractors were re-employed to follow up the work in 2000, maps of African Lovegrass distribution were supplied and a written contract signed before the work began. This time we had comeback if necessary. It was not; the contractor did a thorough, professional job.

The treatment was repeated in 2001 following a summer fire that burnt through most of Talbot Road Bushland in 2001. The maps were particularly useful for locating populations of resprouting African Lovegrass plants for treatment following the fire. The follow-up work in 2000 and 2001 cost $960 and $880 respectively. Maps show that the populations have decreased substantially over this time.



1999

2001

Distribution of African Lovegrass • at Talbot Road Bushland prior to treatment in 1999 and after treatment in 2001.

Table 1. Properties of some herbicides used on bushland weeds.

	Poison schedule	Basic properties	Target weed species	Absorbed by	Mode of action	Average soil half-life	Mobility in soil	Average half-life in water	Bio accumulation	Notes	References
Fluazifop-p-butyl (Fusilade 212®)	**S6**	systemic, selective, non-residual, post- emergent	annual and perennial grasses	foliage	Inhibits acetyl-CoA carboxylase preventing the synthesis of lipids required for growth and maintenance of cell membranes.	15 days	low	stable	high potential in aquatic organisms	Toxic to most grasses except *Vulpia* spp and *Poa annua* . Toxic to fish.	312, 305, 119, 35, 349, 226, 247
Sethoxydim (Sertin Plus®)	**S5**	systemic, selective, post- emergent, non-residual.	some annual and perennial grasses	foliage and roots	Inhibits acetyl-CoA carboxylase preventing the synthesis of lipids required for growth and maintenance of cell membranes.	5-25 days	low-moderate	1 hour to 40 days (dependent on product)		Moderately toxic to aquatic species.	119, 61, 247
Glyphosate (RoundUp®, RoundUp BiActive®, Glyphosate 360® & others)	**S5**	systemic, broad spectrum, non-residual, post- emergent	annual and perennial weeds	foliage	Inhibits the shikimic acid pathway depleting aromatic amino acids required for protein construction.	47 days	low	12 days to 10 weeks	none known	Little to no soil activity. In wetlands use special aquatic formulations.	312, 204, 119, 219, 220
Picloram + Triclopyr (Grazon DS® or Access®)	**S6**	systemic, selective, residual	annual and perennial broadleaf weeds, vines, and woody plants	foliage and root uptake	Auxin mimic - causes uncontrolled, disorganised growth.	20 - 300 days (average 90 days)	moderate-high	1-40 days (depending on sunlight intensity)	slight in fish, none recorded in milk or tissue of mammals	Environmental persistence (up to 2 years). Poses risk of groundwater contamination. Most grasses are resistant. Slight to moderate toxicity to fish and aquatic organisms.	312, 106, 119, 247
Triclopyr (Garlon 600®)	**S6**	systemic, selective, non-residual, post-emergent	annual and perennial broadleaf weeds, vines, and woody plants	roots and foliage	Auxin mimic - causes uncontrolled, disorganised growth.	30 - 90 days (average 46 days longer in cold or arid conditions)	moderate-high	3 hours to 4 days	little to none	Commonly used herbicide. Low to non-toxic to birds, fish and bees. NOTE: The ester formulation is highly toxic to aquatic organisms.	119, 247, 104
Metsulfuron methyl (Brush-off®, Ally®)	unscheduled	systemic, residual, post-emergent	bulbs and broadleaf weeds	foliage and roots	Inhibits acetolactate synthase preventing cell division and thus growth.	14 - 180 days (average 60 days - more persistent in alkaline soils)	moderate - high (more mobile in alkaline conditions)	21-30 days	none known	Biologically active at low rates. Persistence in soil varies according to soil pH, rainfall and soil type. Moderate to low toxicity to fish	110, 119, 226
Chlorsulfuron (Glean®)	**S5**	systemic, residual, post-emergent	bulbs and broadleaf weeds	foliage and roots	Inhibits acetolactate synthase preventing cell division and thus growth.	14 - 60 days (9 months in alkaline soils)	moderate-high	7-14 days	does not accumulate in the milk or tissue of animals	Persistence varies according to soil pH, rainfall and soil type. Low toxicity to birds, mammals, fish and aquatic invertebrates.	111, 222, 35
Clopyralid (Lontrel®)	**S5**	systemic, selective, residual, post-emergent	broadleaf weeds	foliage and some root absorption	Auxin mimic - causes uncontrolled, disorganised growth.	12 days to 1 year (highest under anaerobic conditions and low microbial activity)	high potential	8-40 days	none known	Low toxicity to mammals, birds, fish, aquatic invertebrates and bees. Soluble in water - potential for contamination.	105,169, 312, 61
2,2-DPA/ Dalapon (Propon®, Atlapon®, Cerelon®)	unscheduled	systemic, selective, post-emergent, residual	annual and perennial grasses (also Bullrush and Watsonia)	foliage and roots	Inhibits fat synthesis. Disrupts cell division of root and shoot tips, inhibiting growth.	remains in soil for 2 weeks to 4 months (usually broken down rapidly by soil microbes)	high	days to months (accelerated by increased temperature and pH and high microbial activity)	does not accumulate in tissues (<1% in cow's milk)	Low toxicity to birds, mammals, fish and molluscs. Moderate to high toxicity to shrimp and aquatic insects.	61, 119

Final Note

In the end, environmental weed management is about protection of our unique bushlands through carefully targeted and effective on-ground actions – on-ground actions that prevent introduction or spread of environmental weeds, and work towards their control and sometimes their eradication while protecting complex natural systems. The case studies outlined in the various chapters highlight the importance of having clear goals based on an understanding of the conservation values of a particular site, a thorough knowledge of the weed/s being targeted and a well-defined strategy. Sometimes it takes a series of trials and a number of years to formulate such strategies. To gain an understanding of the effectiveness of those strategies monitoring needs to be in place and results should guide management actions. This kind of framework, together with the resources to support it, is central to effective environmental weed management.

Access to technical resources stands out as particularly important. This seems especially true for weed management in the bushlands of south west Western Australia as they support such an incredibly diverse flora. Effective management is often about knowing and understanding very complex systems. In addition though, technical support is also important for setting up trials and putting in place monitoring. One of the most valuable undertakings of this project has been the work carried out in conjunction with the various land managers setting up replicated trials to test various control options for serious weeds, and the impacts of those control options on native plant communities. This approach provided solid data to guide management actions, and also provided demonstrable outcomes to potential funding sources. At the same time, community volunteers involved gained an understanding of the options available, including the practicalities, costs and impacts of various physical and chemical control methods. They were then able to make informed decisions about implementation of those control options across particular bushland sites.

Typical examples include the trials on management of Yellow Soldier (*Lachenalia reflexa*) in Shenton Bushland, on control of Harlequin Flower, (*Sparaxis bulbifera*) and Tribolium (*Tribolium uniolae*) invading the Brixton Street Wetlands and the work on Taro (*Colocasia esculenta*) along the Gingin Brook. The work on Holly-leafed Senecio (*Senecio glastifolius*) by the Western Australian Department of Agriculture in Albany provided similar outcomes. In all of these examples the results of the trial work provided solid information on which to base management strategies. Importantly the information gathered was also often instrumental in acquiring funding to begin implementation of those strategies across particular bushland sites. Continued funding over time was then often facilitated by the collection of monitoring data. Those data often demonstrated effectiveness of the strategies, regeneration of native plant communities and/or provided justification for funding priorities. There are a number examples throughout the text. Typical is the series of maps illustrating the reduction of Perennial Veldgrass (*Ehrharta calycina*) cover in Shenton Bushland over four years, and the subsequent allocation of resources over that time.

Characteristically, most funding for on-ground works over the life of this project has been in the form of short-term grants, generally applied for by community volunteers, although sometimes in conjunction with local or state government bodies. Often the funding is only available for 12 months and must be re-applied for each year until the work is complete. Such a system has fairly obvious shortcomings. Changes in management personnel, or in the structure of volunteer groups, usually sees a year of funding missed. A season of follow-up control/management work is then missed and the efforts of previous years are wasted. In addition there is little flexibility in the resources that are available. For example, under such funding arangements it can be impossible to find money for weed management following unplanned fire and so an excellent window of opportunity is often missed.

Clearly successful weed management in natural areas is dependent on a consistent effort over many years and access to long-term, secure funding. Certainly, one of the most encouraging trends, over the life of this project, has been witnessing both state and local government commit funding to weed management work originally initiated by the community, through short-term grants. Government bodies seem to be able to do this once it becomes apparent that work is taking place within a clearly defined strategy, that accurate costing is possible and there are demonstrable outcomes. Funding for the work on Harlequin Flower and Tribolium at Brixton St, Perennial Veldgrass, Yellow Soldier and Freesia control at Shenton Bushland and management of the serious weed at Talbot Rd, all initially came about through community efforts but have subsequently been picked up by state or local government, often becoming a part of their recurrent budget. Fundamental to securing this funding has been the availability of on-ground technical support to map the weeds, set up trials and conduct monitoring. The EWAN project officers have provided much of that technical support.

Part of the intention of writing this manual was to highlight the need for state and local government authorities to allocate more resources for technically skilled people, working on the ground, so that environmental weed management can start to be undertaken within this sort of framework. The intention was also to highlight the need to provide technical support for Friends groups and community volunteers who carry out much of the bush regeneration and environmental weed management in south west Western Australia at present. The examples provided through the text illustrate what can be achieved when such support is available.

These examples have mostly focused on protection of particular bushland patches. Although all are drawn from south west Western Australia they have relevance for land managers in other parts of the country. They demonstrate the importance of knowing and understanding particular sites and mostly they illustrate that if we really try, often we can control and manage environmental weeds where they are threatening what remains of our bushlands. Significantly, for most of the case studies described, successful outcomes have been reliant on a combination of community and local, state and federal government efforts.

Walking through Shenton Bushland in spring 2002, much of the Perennial Veldgrass and large populations of Freesia have disappeared. In their place carpets of a native daisy, Slender Podolepis. At Brixton St the Harlequin Flower program is down to hand-weeding remaining isolated populations leaving room for the native herbs to recolonise, and along the Gingin Brook, where the Friends have been working, Taro has been replaced by dense stands of the native Tassel Sedge and seedlings of Paperbarks and Flooded Gum.

Appendix 1 Herbicide Spraying Contract

(Courtesy Bob Dixon, Botanic Gardens and Parks Authority)

1 General

The Contractor shall allow for the supply of all labour, plant and equipment, materials, chemicals and wetting agents required to gain effective control of ______________________________ (weed) in ______________________________(site).

2 Distribution

2.1 All spraying shall be carried out within the bushland of _____________________ (site) in the area on the attached map. Amendments may be made on the agreement of both parties (Friends group/Council and Contractor).

2.2 Herbicide shall be spot sprayed on _________________(weed) only. The Contractor shall be responsible for the cost of purchase of materials and respraying areas of unsatisfactory control, at the appropriate time when suitable conditions prevail.

2.3 The Contractor shall achieve greater than 90 % mortality for _______________ (weed) in sprayed areas. The herbicide manufacturer's guarantee of weed kill shall in no way remove the Contractor of his obligation to respray, should the required mortality rate not be achieved.

2.4 The Contractor shall include in all prices an allowance to achieve the mortality rates mentioned.

2.5 An inspection will be made by ________________________________(Friends group/Council) after the initial spraying to determine effectiveness and so determine the area to be resprayed, if necessary.

3 Mixing

All herbicides are to be thoroughly mixed prior to application and agitated during spraying.

4 Wetting Agent

4.1 The Contractor shall apply a wetting agent in accordance with the herbicide manufacturer's recommendation, e.g. Agral 600 3 mL/L.

4.2 With the herbicide, the volume of water used should be sufficient to ensure an even application of herbicide.

5 Marking Dye

Marking dye shall be used at a rate that is sufficient to see areas sprayed 7 days after application.

6 Spray Drift

The pressure of application shall be kept to a level that prevents excessive spray drift.

7 Plant and Equipment

7.1 All equipment and vehicles must be washed down prior to entering _____________________________________(site).

7.2 All tanks, spray lines to be washed out and thoroughly cleansed, and treated with a product such as Chem Clean before entering ____________________________________(site).

8 Leaks

All leaks (chemical and/or fuel or oils) shall be immediately reported to ____ (Friends group/Council), cleaned up in the appropriate manner and removed from the bushland immediately.

9 Spray Equipment

All plant and equipment used for the application of herbicides shall be suitable for this purpose and be in excellent working order.

10 Control

10.1 Control shall be at a time that _____________________________(weed) is actively growing as agreed to by both parties.

10.2 A log of works shall be completed on a daily basis, showing the following details:

Name of Company _______________________________________ Name of Operator__________________________________

Location/area sprayed____ Date _______________ Time_______________

Weather Conditions e.g.: Fine, showers etc ____

Wind Direction____ Wind Speed_______________________

Chemical Applied____________________________________ Full trade name_____________________ Rate________________

11 Warning Signs

It is the operator's responsibility to warn any members of the public who venture into the bushland during the spraying to withdraw.

12 Harmful Chemicals

The Contractor shall not use a herbicide in any manner or circumstance that is dangerous, harmful or injurious to health (refer regulation 20 (1) of the Health (Pesticides) Amendment Regulations 1986).

13 Licence

A copy of the Company's 'current' Pesticides Operator's Licences, stating chemicals that individual Operators are registered to apply, together with the names of Operators who will be applying herbicides under this Contract, must be submitted with signed specification. The contractor shall guarantee the competency of Operators applying herbicides under this Contract.

14 Commencement and Completion

The contractor shall notify ____ (Friends group/Council) at least 24 hours prior to starting and on completion of work.

I hereby agree to the above specification

Signature Name of Company Date

Please Print Name

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