A guide to managing and restoring wetlands in Western Australia

Managing wetland vegetation

In Chapter 3: **Managing wetlands**

Version 1

Australian Government

Department of Environment and Conservation

Our environment, our future

Introduction to the guide

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

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

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

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

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

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

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

Contents of the guide

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

'Managing wetland vegetation' topic

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Recommended reference

When referring to the guide in its entirety, the recommended reference is: Department of Environment and Conservation (2012). *A guide to managing and restoring wetlands in Western Australia*. Department of Environment and Conservation, Perth, Western Australia.

When specific reference is made to this topic, the recommended reference is: Department of Environment and Conservation (2012). 'Managing wetland vegetation', in *A guide to managing and restoring wetlands in Western Australia*, Prepared by J Nichol, Department of Environment and Conservation, Perth, Western Australia.

Contents

Case studies

Before you begin

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

INTRODUCTION

Wetland plants are an important part of the state's biological diversity. It is estimated that wetland **taxa** form more than 20 per cent, or 3,000 of Western Australia's approximate 12,500 flora.[1]

The **vegetation** also constitutes part of the wetland **ecosystem**, playing a key role in many physical, biological and chemical **wetland processes**, helping to maintain a stable ecosystem and defining a wetland's **ecological character**. As such, vegetation change can significantly influence the long-term health and values of a wetland.

WA's wetlands can be degraded by a range of threatening processes that impact upon wetland flora and vegetation. This is telling in the number of wetland **ecological communities** that are threatened: thirty-three of WA's sixty-nine threatened ecological communities are wetland communities defined or reliant on (vascular) plant taxa.[1] Weeds are usually prevalent in wetlands that have been subject to disturbance.

Vegetation changes can either occur naturally or because of human influences. This topic focuses on managing human-caused vegetation change in natural wetlands. Most human-caused vegetation changes are detrimental and can lead to further degradation of a wetland ecosystem. This topic outlines the steps wetland managers can take to manage native wetland vegetation in order to maintain a wetland's natural values. The information in this topic applies to the management of vegetation that is currently degraded, or that is in good condition or within acceptable limits of change, so as to prevent the vegetation becoming degraded.

Specifically, this topic is designed to assist wetland managers to:

- identify the three main types of vegetation change that occur within a wetland and determine the type and extent of these changes in a given wetland
- determine an appropriate level of intervention
- plan management actions.

Requirements for revegetating or rehabilitating wetlands as a condition of development approval, an offset, or a vegetation conservation notice under the *Environmental Protection Act 1986* or relevant planning legislation are not addressed in this topic. These mechanisms may have specific requirements, such as completion criteria and specific timeframes.

➤ For guidance on these matters, see:

- *Rehabilitation of terrestrial ecosystems*[2]
- *Guidelines checklist for preparing a wetland management plan*[3]
- Chapter B4 of *Environmental guidance for planning and development*[4]

Taxa: a taxonomic group (the singular being taxon). Depending on the context, this may be a species or their subdivisions (subspecies, varieties etc), genus or higher group.[6]

Vegetation: combinations of plant species within a given area, and the nature and extent of each area

Ecosystem: a community of interdependent organisms together with their non-living environment.

Wetland processes: the dynamic physical, chemical and biological forces within a wetland, including interactions that occur between wetland organisms, within the physical/chemical environment, and interactions of these

Ecological character: the sum of a wetland's biotic and abiotic components, functions, drivers and processes, as well as the threatening processes occurring in the wetland, catchment and region

Ecological community: naturally occurring biological assemblages that occur in a particular type of habitat

There is no substitute for maintaining the natural characteristics of wetland vegetation. Regeneration and revegetation activities may never completely re-establish natural wetland processes.[5] Prevention, and maintaining or improving the **resilience** of the vegetation, are key strategies. In the absence of vegetation changes, wetland managers can manage wetland vegetation by:

- keeping a watch for vegetation change, particularly weeds
- managing the dryland surrounding the wetland (sometimes designated as a **wetland buffer**) to help protect the wetland from potential impacts from surrounding land uses and to help maintain its natural processes
- retaining, or where possible, reinstating **ecological linkages**
- where warranted, surveying the wetland vegetation and considering contingencies such as seed storage that can be used in the event of significant vegetation change.

➤ Programs providing funding, labour, training and technical guidance for wetland vegetation management are outlined in the topic 'Funding, training and resources' in Chapter 1.

It is strongly recommended that anyone intending to carry out regeneration or revegetation activities consider doing so within the framework of a wetland management plan. A wetland management plan provides a structured way of deciding on priorities and tasks to make the process as effective, efficient and successful as possible. For large, complex or significant wetlands it is invaluable.

➤ Further guidance in provided in the topic 'Wetland management planning' in Chapter 1.

Resilience: capacity of a system to absorb disturbance and reorganise while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks

Wetland buffer: an interface adjoining a wetland that is designated to assist in protecting the wetland's natural values from the threats posed by the surrounding land use(s)

Ecological linkage: a network of native vegetation that maintains some ecological functions of natural areas and counters the effects of habitat fragmentation[6]; a series of (both contiguous and non-contiguous) patches of native vegetation which, by virtue of their proximity to each other, act as stepping stones of habitat which facilitate the maintenance of ecological processes and the movement of organisms within, and across, a landscape[7]

extra information

WA's wetland vegetation: background information

WA's wetland plants are remarkable and important for many reasons. Wetland flora contributes to the incredible biodiversity and endemism found in WA, in parts of the Kimberley, Pilbara and Goldfields regions, and in the south-west, which is a centre of exceptionally high species richness and endemism and is one of the world's 25 biodiversity hotpots.[2]

For more information on WA's wetland vegetation and flora refer to:

- the topic 'Wetland vegetation and flora' in Chapter 2, which documents the remarkable vegetation and flora of WA's wetlands
- the topic 'Wetland ecology' in Chapter 2, which provides information on the ecological role played by wetland vegetation.

In seeking to provide guidance on managing the vegetation of WA wetlands, there are many limitations to how specific or detailed the information can be. The vegetation in WA's wetlands ranges from forests to tiny moss pillows, extremely diverse to fairly limited, and relatively well-documented to those containing flora not yet documented by science.

Useful contacts and resources for additional information include:

- *Restoring Natural Areas in Australia* (Buchanan 2009)[8]
- Florabank's Native Vegetation Management Tool: www.florabank.org.au
- The Australian Association of Bush Regenerators www.aabr.org.au

extra information

WA's wetland vegetation: background information (cont'd)

- Revegetation Industry Association of WA www.riawa.com.au
- Wildflower Society of Western Australia http://members.ozemail.com.au/~wildflowers/policies.htm
- Greening Australia[9] http://live.greeningaustralia.org.au/nativevegetation/pages/page116.html
- *Restoring Perth's Banksia woodlands* (BGPA, in preparation)

WHAT ARE THE MAIN TYPES OF VEGETATION CHANGE IN WA WETLANDS?

Changes to natural wetland vegetation can be categorised into three main types:

- composition
- structure
- density.

These are defined below.

Composition

A 'composition' change is any change to the assemblage of individual plant species within a plant community or group of communities (see Figure 1 and Figure 4). Examples of a 'composition' change include:

- a plant species is lost from the community
- a new plant species enters the community
- a plant species is replaced in the community with another plant not found in the original community

A possible result of a 'composition' change is the establishment of a new assemblage of plants, so the community itself has been altered.

Figure 1. Impacts to this wetland have resulted in a change in composition, with weeds replacing native species in the understorey. Photo – C Mykytiuk.

Structure

A 'structure' change is any change to the configuration or arrangement of a plant species within a community. A community consists of a suite of species, and one or more of those species may become more dominant over others, but the same suite of species remains (as opposed to a change in 'composition') (see Figure 4).

For example, a wetland may became more saline over time, allowing one species already found in the plant assemblage to become more dominant because it is more tolerant of the more saline environment. For example, samphires may already be present in the community but may become more dominant with increasing salinisation.

Similarly, if abstraction of groundwater causes the death of a significant proportion of trees of a particular species in a forested wetland (that is, supporting canopy with greater than 70 per cent cover), the change in structure from a forest to a woodland (which supports less than 70 per cent cover) would constitute a change in structure. In addition to trees, other life forms in WA wetlands are shrubs, herbs, grasses, sedges and climbers; and layers in WA wetlands include shrubland, herbland, grassland, sedgeland and combinations of these.

Structural change can also be natural, with relative species dominance changing over time as a community 'matures' following a disturbance, such as a flooding event or fire. This is known as succession in a plant community. It is important to understand the cause of structural changes in a community, and determine if this is natural or not, and if management intervention is required, or not.

It is important to keep in mind that many wetlands naturally do not have a stereotypical zonation from an inundated central area vegetated with aquatic plants and extending out to sedges, shrubs and trees (as shown in Figure 17). Particularly in waterlogged wetlands, there is often a mix of these types of plants throughout, with plant patterning reflecting smaller-scale habitats within these wetlands (Figure 2 and Figure 3).

Figure 2. Wetland vegetation of a seasonally waterlogged wetland.

Figure 3. Wetland vegetation of a seasonally waterlogged wetland.

Biomass: the total mass of biological material (living or dead), usually expressed as live or dry weight per unit area or volume

Senescence: the natural aging and subsequent death of an organism

Density

A 'density' change is any change to the total amount of plant material or **biomass** in a wetland. Examples of a density change include a reduction in density due to the removal of plants through clearing or **senescence**, or an increase in the density due to re-growth following a fire.

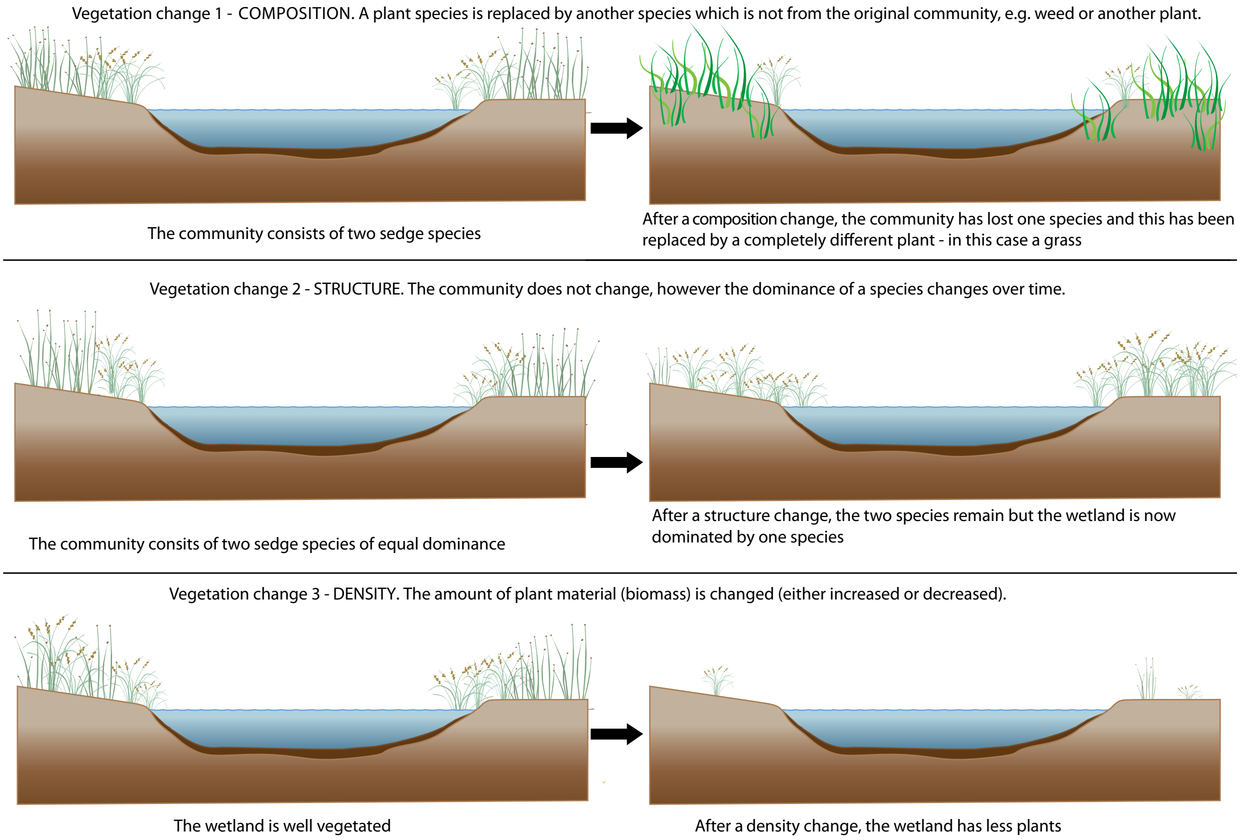

Figure 4. Schematic representation of the three main types of vegetation change in wetlands.

The reasons for vegetation change are often complex and vegetation change itself may result in the generation of other threats developing over time, which may then lead to further vegetation change occurring. For example, clearing resulting in a 'density' change to wetland vegetation, may allow the introduction of weeds leading to 'composition' and 'structure' changes. Figure 5 schematically represents clearing as a vegetation change and how this event may lead to other vegetation change events occurring over time.

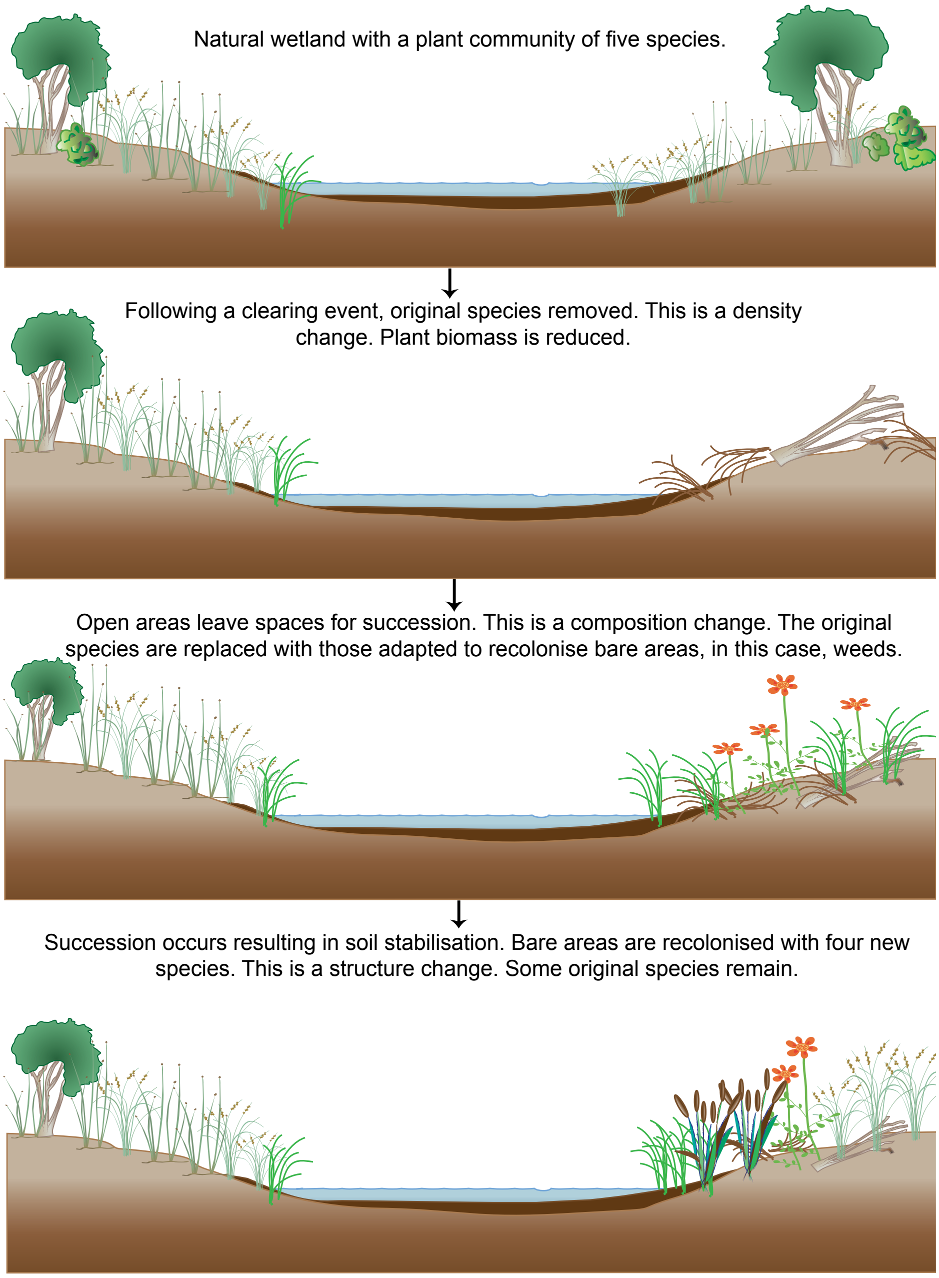

Figure 5. Vegetation clearing leading to other vegetation changes.

Natural responses to change: colonisation and succession

Succession is defined as progressive change in species composition and/or structure that occurs following disturbance of a site.[10] It can be caused by a natural or human-induced event such as fire, clearing or grazing. Following the disturbance event, the changed physical environment is colonised by a series of plant communities until the vegetation reaches a final 'equilibrium state'. Initially, colonising plants (or 'pioneers' or 'disturbance opportunists') grow, develop and modify the environment so that other plants can successively join or replace the initial colonisers, until the maximum number of species exist in that environment.[11] Initial colonising plants are those that are adapted to respond rapidly to opportunities for growth and survival in highly disturbed environments.

Colonising plants in WA wetlands include species such as wattles (*Acacia*), stinkwoods (*Jacksonia*) and spearwood (*Kunzea*) species which are mid-storey plants that produce large volumes of seed (Figure 6 and Figure 7). These seeds remain viable for long periods in readiness to germinate in response to an environmental change such as fire or sudden exposure to light that is significant enough to trigger germination, and start the process of succession. These plants can grow very rapidly and prolifically in order to take advantage of the good growing conditions and lack of competition from other native plants and weeds (Figure 8). Many succession species also have relatively short life spans, for example, many *Acacia* species and stinkwood (*Jacksonia sternbergiana*) live approximately 14–20 years, as opposed to some long lived slow growing species such as jarrah (E*ucalyptus marginata*) which can live up to 400 or more years.[12] When colonisers die off, conditions are often suitable for other species to regenerate. Coloniser species may also enhance the site conditions for later species – for example the legumes (*Acacia* species and pea plants such as *Jacksonia*) are able to 'fix' atmospheric nitrogen, increasing the nitrogen available in the soil for other species.

Figure 6. Panjang (*Acacia lasiocarpa*) is a common succession species in areas of the south west of WA. Photos – M Hislop (main) M Hancock (close up). Images used with the permission of the Western Australian Herbarium, Department of Environment and Conservation http://florabase.dec.wa.gov.au/help/copyright.

Figure 7. Stinkwood (*Jacksonia sternbergiana*) is a common succession species in areas of the south west of WA. Photos – K C Richardson (main), R Davis (inset). Images used with the permission of the Western Australian Herbarium, Department of Environment and Conservation http://florabase.dec.wa.gov.au/help/copyright.

However, dense, very old stands of some coloniser species and an absence of other species may indicate that the seed bank of other species is likely to be exhausted. It isn't uncommon for landowners to express a desire to 'get rid of' these species in the belief that they are preventing other plants from establishing. However, such dense stands may be natural and part of the structural arrangement of vegetation in specific habitat types within or surrounding a wetland. These colonising plants play an important role and should not be prematurely removed for aesthetic reasons if the natural wetland vegetation is to be retained. For example, following establishment, acacias and stinkwood stabilise the soil, develop soil nutrients, and provide shade and habitat for a period of time before other more long-lived wetland understorey and overstorey species such as flooded gum (*Eucalyptus rudis*) can establish and gradually out-compete the succession species.

Figure 8. Prolific growth of *Kunzea* sp. has occurred in the older area (left hand side) of a firebreak within a seasonally waterlogged wetland, in the southern Perth suburb of Forrestdale. Photo – J Higbid/DEC.

IDENTIFYING VEGETATION CHANGE

Monitoring will allow vegetation change events to be identified and may help to determine the cause of the change and effects of the change.

Identifying change of wetland vegetation through visual observations over time can provide considerable information on the nature and extent of vegetation changes. Examination of aerial maps and photographs from monitoring points over time are other simple methods of identifying change.

- Google Earth www.google.com/earth supplies a free software program that provides online access to aerial photography covering WA. Some areas have many years of aerial photography (time series), which can assist with identifying vegetation change.
- Aerial photography can be viewed and purchased from Landgate's Map Viewer www.landgate.wa.gov.au/bmvf/app/mapviewer/ and NearMap www.nearmap.com.

To determine wetland vegetation change accurately, the following characteristics of wetland vegetation can be monitored regularly to determine the degree and rate of the change:

- extent
- species composition
- structure (height class and dominance); and
- vegetation density (percentage cover)[13]

These observations will provide information on how rapidly the changes are occurring. This information is important in decision-making for undertaking intervention projects which are discussed in detail later in this topic.

If time or money is not available for monitoring vegetation and other wetland parameters, photo points may be useful in determining if changes are occurring. Photo points are simple, fast and relatively cheap to establish. The drawback of photos is that they only provide an indication that a change is occurring or has occurred and may not enable that change to be quantified. Photos such as those in Figure 9 showing weeds being controlled in a wetland are useful as monitoring points for noticing changes over time. Small, incremental changes may be difficult to detect in monitoring photos, and it may take a number of years before change is noticeable.

Figure 9. Photo monitoring is an effective way of capturing information at a point in time. This photo series shows the extent of *Watsonia meriana* var. *bulbillifera* within Brixton St wetland in response to weed management over a period of six years. Photos - K Brown/DEC.

➤ For a guide to photo points for monitoring purposes, see the Land for Wildlife program's Wildlife Note No. 9 *Photographic monitoring of vegetation*.[14]

➤ For additional detail on monitoring wetland vegetation and other parameters please see the topic 'Monitoring wetlands' in Chapter 4.

Technology now offers opportunities to monitor vegetation in new ways, making use of aerial photography and high-resolution digital airborne imagery to detect indications of canopy change, water use and plant health. These techniques may be suitable for large, complex wetlands or those in remote or inaccessible areas.

➤ For more information, see CSIRO (www.csiro.au/Organisation-Structure/Divisions/Land-and-Water/Environmental-Earth-Observation.aspx)

Where monitoring has not taken place and the vegetation prior to change was not documented, it is likely that it will need to be inferred. Photographs and aerial photographs can provide insight; if this information isn't available it may be useful to examine a suitable benchmark or **reference wetland** that shares the same characteristics as the wetland in question. Alternatively it can be very useful to gain historical insight from people familiar with the wetland in the past, who may be able to identify changes that have occurred and their causes.

Reference wetland: a wetland used to provide a model for planning a management project

Dynamic: a process or system which is characterised by constant change or activity

WHAT ARE THE EFFECTS OF VEGETATION CHANGE ON WETLANDS?

Vegetation change can significantly impact on the physical, biological or chemical processes existing within a wetland. Detrimental changes to vegetation in a wetland can occur at different rates, be subtle or substantial, involve different plant species, and will have a varied impact on wetland condition and functionality.[5] The effects of vegetation change may include:

- changes to habitat for native animals, fungi, algae and bacteria
- changes to the overall level of primary production by plants, resulting in changes to food webs that provide native animals, fungi and bacteria with food/energy
- changes to the chemical characteristics of the water. For example, a change in the amount of tannins in the water, and in the uptake of nutrients in the wetland with resulting changes to the types and density of algae
- changes in the physical structure of the wetland. For example, rates of erosion and sedimentation determined by vegetation can affect the bathymetry of a basin
- localised extinctions of plant species and vegetation communities

➤ For more information on the ecological role played by wetland vegetation, see the topic 'Wetland ecology' in Chapter 2.

WHAT CAUSES VEGETATION CHANGE IN WA WETLANDS?

Plants respond to a range of factors, such as water regime, soil wetness, salinity, pH, temperature, light, nutrients and competition.[15] These factors fluctuate within wetlands because of a variety of natural or human-induced events.

Natural causes

Due to the **dynamic** nature of wetlands in WA, managers should expect some natural vegetation change and allow for subtle changes over time.[16] Natural vegetation changes occur in wetlands in response to events such as drought, floods, cyclones, boom and bust animal populations, and fire caused by lightning strikes. These affect vegetation germination, growth and survival and can result in natural short, medium or long-term changes to composition, structure and density of vegetation. For example, a detailed study of the Becher wetlands in Rockingham found that fluctuations in structure and density of populations of the annual groundcover gota kola (*Centella asiatica*, Figure 10), occurred regularly over five years as local climatic and flooding conditions varied.[17]

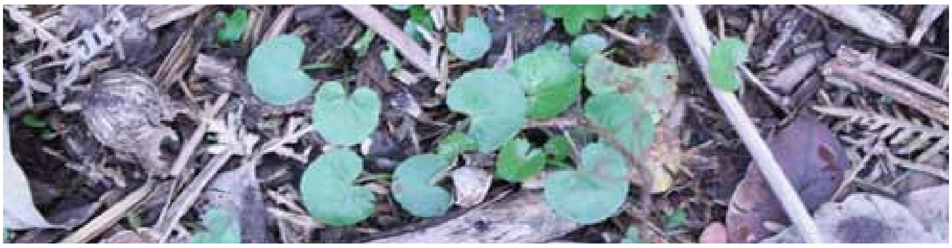

Figure 10. *Centella asiatica* density and structure was shown to fluctuate naturally over time in the Becher wetlands. Photo - J Nichol/DEC.

Human causes

Some of the most common human-induced causes of vegetation change are:

- weed infestations
- grazing by livestock or other introduced or nuisance animals
- manual clearing
- fire
- disease
- altered hydrology
- salinity
- other changes to water quality including **eutrophication** and acidification.

It is not uncommon for a wetland to have been subject to more than one cause of vegetation change over time or at the same time. For example, in urban areas, many wetlands were historically grazed, causing altered hydrology and water quality, and weed invasion. Once urbanised, altered fire, hydrology, water quality and weeds continue to cause vegetation change.

Table 1 below summarises how these **threatening processes** can affect vegetation. Many of these causes of vegetation change are covered in detail in other topics of this guide.

Eutrophication: the nutrient enrichment of a water body, which can trigger prolific growth of plant material (phytoplankton, macrophytes or both). May occur naturally over geological time or may be human-induced.

Threatening processes: processes that threaten the survival, abundance or evolutionary development of a native species or ecological community

Table 1. Common threats to wetlands and examples of their effect on wetland vegetation.

Activity or threat to wetland	Type of change to vegetation	Example	More information
Clearing - manual	Density	Plants are manually removed via a machine, so extent of vegetation altered	
	Structure	Clearing removes the understorey species and changes the arrangement	
	Composition	Clearing activity transports weeds into the community which then outcompete native species	
Livestock and feral animals	Density	High nutrient levels cause algae to proliferate, out-competing native plants and reducing total plant biomass in the wetland.	See the topic 'Livestock' and 'Introduced and nuisance animals' in Chapter 3
	Structure	Areas of the wetland are preferentially spot grazed by horses, while droppings are left in another area	
	Composition	Palatable species that are selectively grazed are lost from the wetland. Weeds are introduced in faeces.	
Weeds	Density	Typha (*Typha orientalis*) invades a population of bare twigrush (*Baumea juncea*) which is much slower growing. The typha spreads and vegetation density in the community alters as the typha is much denser (has a higher biomass).	See the topic 'Weeds' in Chapter 3.
	Structure	Typha (*Typha orientalis*) invades a population of bare twigrush (*Baumea juncea*) which is much slower growing. The typha spreads and vegetation structure changes- the *Baumea* dies off because it has been taken over and only a small remnant remains	
	Composition	Typha (*Typha orientalis*) invades a population of bare twigrush (*Baumea juncea*) and the baumea cannot compete for sunlight and dies. It is completely replaced in the community by the typha	
Phytophthora dieback	Density	Potentially greater biomass due to severe weed invasion post-infection	See the topic 'Phytophthora dieback' in Chapter 3
	Structure	Increased dominance of resistant native and weed species	
	Composition	Loss of susceptible plant species from the wetland	

Activity or threat to wetland	Type of change to vegetation	Example	More information
Secondary salinity	Density	Salinity of water increases causing some wetland plants which are not tolerant to die, reducing overall cover	See the topic 'Secondary Salinity' in Chapter 3.
	Structure	Where saline water is highest; many plants of non-tolerant species are dying and more tolerant species are taking over and dominating, changing the vegetation structure	
	Composition	More saline tolerant weed species move into areas where plants have died.	
Eutrophication (increased nutrients)	Density	Quality of water changes causing some wetland plants which are not tolerant to die reducing overall cover	See the topic 'Managing Water Quality' in Chapter 3.
	Structure	More tolerant species or ones which thrive in high nutrient environments then take over and dominate, changing the vegetation structure	
	Composition	Weeds, which have more tolerance for high nutrient levels, move into the plant community	
Altered hydrology	Density	Reduced water depth means some plants die reducing overall cover of vegetation leaving bare areas	See the topic 'Managing hydrology' in Chapter 3
	Structure	More tolerant species spread and take over from other species	
	Composition	Dryland species from different plant assemblage or weed species spread into drier zones.	
Altered fire regime	Density	Fire can kill individual plants, decreasing density. Plants may germinate in response to fire, increasing density. Either way, vegetation density is altered by fire events	
	Structure	Fire may favour burning particular species in a community over others, thereby altering the dominance of some species over time. Relative species presence will change over time with succession.	
	Composition	Fire tends to favour fire-tolerant species and disadvantage fire-sensitive species. Fire events kill vegetation allowing areas to be opened up for plants potentially not from the local community to invade. Some weedy plant species thrive in fire environments.	

Clearing of native vegetation

Clearing is regulated under the *Environmental Protection Act 1986.* Under section 51A of the Act, clearing is defined as:

(a) the killing or destruction of; or

(b) the removal of; or

(c) the severing or ringbarking of trunks or stems of; or

(d) the doing of any other substantial damage to,

some or all of the native vegetation in an area, and includes the draining or flooding of land, the burning of vegetation, the grazing of stock, or any other act or activity, that causes —

(e) the killing or destruction of; or

(f) the severing of trunks or stems of; or

Clearing of native vegetation (cont'd)

(g) any other substantial damage to,

some or all of the native vegetation in an area.

The Act establishes it to be an offence to cause or allow clearing of native vegetation unless it is done in accordance with a clearing permit, or is exempt. The Environmental Protection (Clearing of Native Vegetation) Regulations 2004 describe the administration of permits.

The regulations apply to all native vegetation including native aquatic or terrestrial vegetation, but not vegetation in a plantation or which was intentionally sown, planted or propagated unless that vegetation was sown, planted or propagated as required under law.

The taking of flora, including seeds, flowers, stems and all other parts of native plants, is regulated under the *Wildlife Conservation Act 1950*. On Crown land, taking of flora for any purpose requires a licence. On private property, the taking of flora requires the land owner's permission, and a licence is required for the sale of any flora that is taken. For further information on flora licences, contact DEC. Clearing that is done in accordance with a licence issued by DEC under the *Wildlife Conservation Act 1950* does not require a clearing permit.

For information on legislation relating to native vegetation clearing, please see the topic 'Legislation and policy' in Chapter 5.

MANAGING DETRIMENTAL VEGETATION CHANGE

There are two main phases when managing detrimental vegetation change:

1. addressing the causes of the vegetation change
2. managing the vegetation

Addressing the causes of detrimental vegetation change

The first step of managing detrimental vegetation change is addressing the cause of the change. This entails identifying the cause and then deciding whether to:

- stop or minimise the cause
- prevent the cause from re-occurring
- take no action at all

Even when the outcome of this step is to take no action at all, it is an essential step which determines how to proceed. If this is not taken into consideration, efforts at regeneration and revegetation may fail, be more expensive, less efficient and even detrimental to a wetland environment.

Many wetland managers in the Wheatbelt face the issue of vegetation change caused by secondary salinity. Secondary salinity is a complex, landscape-scale issue and its management typically involves change in land use across landscapes and a range of expensive intervention measures that are beyond the scope of many wetland managers. If the catchment is not identified as being a priority for biodiversity recovery by regional or state organisations, it is highly unlikely that there will be potential to achieve the vegetation composition, structure and density that existed prior to secondary salinisation. In this scenario, establishing that secondary salinisation of the wetland cannot be halted is the first step in determining the way forward. Wetland managers can then establish whether natural colonisation of native salt-tolerant species is likely to occur and if so, they can prioritise activities to reduce threats to regeneration, such as salt-tolerant weeds and livestock grazing, so that **adaptation** to changing conditions occurs without being compromised by threats that can be managed.

Table 3 cross-references the relevant topics of this guide which provide guidance on addressing the causes of vegetation change.

Table 2. Information on how to manage the cause of vegetation change

Threat to vegetation	Information on how to manage this threat
Weeds	'Wetland weeds' topic, Chapter 3.
Grazing by livestock	'Livestock' topic, Chapter 3
Damage by introduced and nuisance animals	'Introduced and nuisance animals' topic, Chapter 3
Altered hydrology	'Managing hydrology' topic, Chapter 3
Phytophthora dieback	'Phytophthora dieback' topic, Chapter 3
Secondary salinity	'Secondary Salinity' topic, Chapter 3
Eutrophication (increased nutrients)	'Water quality' topic, Chapter 3
Acid sulfate soils	'Water quality' topic, Chapter 3

Weeds require a special mention, because as well as being a cause of vegetation change, weed invasion is also an outcome of every other type of vegetation change listed above. The planning of weed management should be coupled with planning of native vegetation management. The location, size of the area, amount of weeds to be controlled and rate of control should be dictated by the resources available and the rate at which natural regeneration or revegetation is expected to occur following the removal of weeds. The **Bradley method**[16] is effective, that is, working from more intact areas of vegetation towards more degraded areas. This allows natural regenerative processes within the environment to assist with regeneration and revegetation.

Managing vegetation

Deciding whether to actively manage the vegetation

Once the cause of vegetation change has been addressed (identified, stopped, reduced, prevented in future or not acted upon), the wetland manager can aspire to either:

1. **restore** the wetland vegetation composition, structure and density as much as possible, or

2. **rehabilitate** the wetland to create a new, self-sustaining native plant community that can survive in the altered environmental conditions, while still being as close to the original community as possible.

Alternatively, following an examination of these options, it may be determined that the scope for restoration and rehabilitation is too limited and the costs too high to proceed with either option. A decision may then be made to manage the wetland to limit further loss of wetland values. Ultimately, it is necessary for wetland managers to ensure that they are directing limited resources to those sites that achieve the best possible nature conservation outcomes.

Adaptation: the process by which an organism becomes fitted to its environment

Bradley method: working from the most intact parts of a bushland area out towards more degraded areas, to allow natural regeneration to occur, for example, when weeding

Restoration: returning an ecological community to its pre-disturbance or natural state in terms of abiotic conditions, community structure and species composition

Rehabilitation: the re-establishment of ecological attributes in a damaged ecological community although the community will remain modified

Private landowners may decide it is a priority to rehabilitate their wetland. Public land managers with responsibility for large areas of land (multiple wetlands), and other organisations involved in regional land management activities, typically need to prioritise sites to be managed. Some basic principles include prioritising:

- wetlands that are of high conservation value
- wetlands that are in better condition before those in worse condition
- wetlands that are improving by themselves rather than deteriorating
- those that will take less work to get back to a more natural state.[18]

The decision to restore, rehabilitate or to take a minimalist approach (including not to act at all) needs to be made early on in the management process in order to manage expectations and to set realistic objectives for the long-term management of the vegetation change event. It is also important to note that the required level of intervention may alter over time and will require frequent re-evaluation.[16]

From a nature conservation perspective, restoration is always most desirable, but it is often not feasible. It will depend on whether it is possible to address the cause of the vegetation change and how significant changes to the wetland and its vegetation are. The development of a management plan that describes the objectives for the wetland is a good way to work logically through this decision-making process.

➤ A process for wetland management planning is described in the topic 'Wetland management planning' in Chapter 1.

The rate at which a vegetation change event occurs can be a strong indicator of whether an intervention response is the most appropriate action. Rapid vegetation changes often signify that a critical **threshold** has been reached.

A rapid rate of vegetation change is also likely to allow for opportunities for other threatening processes to occur which may exacerbate the vegetation change event or degrade the wetland further.

The more that vegetation changes, the more challenging it may be to instigate meaningful intervention, the greater the effort required and therefore potentially the higher the management costs.[19,10] Early detection and evaluation of change is vital for preserving existing vegetation and values.[16,20]

The cumulative effect of allowing wetlands with small vegetation change events to continue to degrade is likely to result in additional management costs in the future.

Managing vegetation: choosing regeneration or revegetation

If a wetland manager has determined that either restoration or rehabilitation is feasible, they can usually choose one or more of the following three strategies:

1. where possible, allow for the natural processes such as regrowth and recruitment within the wetland to repair the vegetation; known as 'regeneration'
2. carry out activities to optimise natural regeneration processes that repair the vegetation; known as 'assisted regeneration', including fire, smoke and smoked water
3. where necessary, introduce plants/seeds to the wetland that are adapted to the new conditions following the vegetation change event; known as **revegetation**.

Wherever regeneration potential exists, it should always be the default option. Regeneration provides much greater potential for achieving self-sustaining wetland ecosystems and a far greater chance of approximating the natural diversity of a wetland. Natural and assisted regeneration techniques are natural and non-invasive/minimally invasive respectively. They are also cost-effective.

Thresholds: points at which a marked effect or change occurs

Revegetation: return vegetation (indigenous or otherwise) to an area

Figure 11. A wetland near Yanchep, north of Perth, where following a fire, the potential for natural regeneration is likely to be high, unless actual acid sulfate soil generation has occurred. Photo – T Calvert/DoE.

Endemic: naturally occurring only in a restricted geographic area

Propagate: grow plant specimens from parent material

Revegetation is usually required only when a wetland will continue to degrade or will remain in a degraded state without human intervention. Revegetation tends to require significantly more resources and time. Being an invasive technique, it also poses risks that regeneration does not. There are also significant limits to our ability to achieve natural diversity through revegetation. For example, in the area encompassing Perth and surrounds (Moore River to Dunsborough), 74 per cent of the 1,187 native wetland plant taxa are **endemic** to WA.[1] Many of these taxa have not yet been successfully **propagated** (bred) and so are not able to be used in planting programs.

Assessing the potential for natural regeneration

The wetland manager plays no active role in natural regeneration, other than monitoring, and where necessary, working to reduce threatening processes. Natural regeneration is the least invasive, and potentially cheapest way to reverse detrimental vegetation change.

Regeneration uses the natural processes such as regrowth and recruitment to repair the vegetation. Understanding the potential for regeneration of wetland vegetation involves assessing the resilience and reproductive capacity of the wetland vegetation following a vegetation change event.

Natural regeneration is more likely to occur when the cause of vegetation change is a natural process, such as fire, and where this process is not compounded by other impacts. Where fire has occurred, for example, the best approach is to carry out regular inspections to ensure that the area is not being invaded by weeds, and that the fire has not resulted in the generation of actual acid sulfate soils (Figure 11).

Regeneration may or may not result in similar composition, structure and density of wetland vegetation compared to its original state. The vegetation change event may have changed the conditions required for one of these aspects to be achieved. For example, *Phytophthora cinnamomi* can kill individuals of species that are susceptible to the pathogen, changing the vegetation composition; similarly the export of nutrients in ash following a fire may limit the density of regrowth.

This principle does not always apply when altered hydrology has caused the death of mature plants in a tree population. These mature species may be adapted to the existing water regime and may be lost as a result of changes to hydrology, if changes are too fast or too extreme for them to adapt. However, their progeny may develop root morphologies suitable to the new water regime, allowing a plant population to survive even if individuals are lost.

It is important to take into account the timeframes required for regeneration processes, for example, the season in which plants germinate, vegetatively reproduce or re-grow.

As described earlier, colonisation and succession are natural processes of recovery.

Regeneration is reliant upon:

- a source of healthy seed or **propagules**
- a receptive seed bed
- suitable climatic conditions
- suitable water regimes
- protection from grazing/impacts of animals
- low competition from weeds or other native plants
- the absence of harmful pathogens or other disease organisms

Regeneration occurs via:

- the release of seed during/after the event
  For example, modong (*Melaleuca preissiana*) are prolific seed producers and produce a seed rain each season. The seeds are very small and can germinate in large numbers in response to episodic events such as heavy rainfall and fire, where these provide opportunities for germinants to establish. The majority of wetland shrubs and trees in WA are long-lived and experience episodic **recruitment** events under the right conditions. Assessing seed production and viability will help establish the likelihood of germination of seed-setting species.
- suitable conditions for remaining individuals to produce seed after the event
- suitable conditions for re-growth of existing individuals via **epicormic** buds (Figure 12), **lignotubers** etc.
- suitable conditions for vegetative growth to occur via **rhizomes** or **stolons**
- This is particularly relevant for many **sedges**.
- suitable conditions for re-growth of existing individuals via **underground storage organs** such as bulbs, tubers and corms.
- Underground storage organs such as bulbs, tubers and corms allow plants to renew. These organs allow plants to enter a state of dormancy where conditions are extreme, such as during drought and fire. The underground storage organs of some species can remain dormant in the soil for years and still remain viable, and for some, sprouting is stimulated by fire. Twenty-two percent of wetland flora in the southern Swan Coastal Plain (the Perth metropolitan region and surrounds from Moore River to Dunsborough) renew from underground storage organs.[1] If these remain unaffected by detrimental change, a significant amount of regeneration can occur.
- the soil seed bank being intact and viable
- The **soil seed bank** is more likely to be intact if the soil hasn't been disturbed. This factor will affect the degree to which species will germinate from soil seed banks (Figure 13).

Propagule (plant): any part of a plant from which a new plant can grow, including seeds, bulbs and rootstocks

Recruitment: addition of new individuals to a population (usually through reproduction)

Epicormic buds: dormant vegetative buds that are embedded beneath the bark, which have a regenerative function after crown destruction

Lignotuber: a large woody swelling of the plant stem that occurs at and below the soil surface. Regrowth from lignotubers can occur following fire, drought and grazing.[22]

Rhizomes: stems that are buried underground

Stolons: stems that usually run horizontally along the soil surface

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

Underground storage organs: specialised fleshy organs such as corms, bulbs and tubers that allow plants to flourish in nutrient deficient soils or to die back and enter a state of dormancy when conditions are extreme, such as during fire or drought[23]

Soil seed bank: the natural storage of seeds, often dormant, within the soil

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

Figure 12. Epicormic growth of a fallen *Melaleuca rhaphiophylla* at Maramanup Pool, Baldivis, south of Perth. Photo – J Higbid/DEC.

Figure 13. The degree to which the soil has been disturbed will have an effect on how viable the soil seed bank is. Photo – L Perera.

➤ *Are there seeds in your wetland*?[21] describes how to assess the seed bank in a wetland's sediment. This can be used to help determine which species' seeds are present and their viability.

- suitable **seed dispersal mechanisms** occurring to enable seeds to reach the area Many wetland plants disperse seeds using wind, water and animal vectors. Some have a wide distribution in many areas of WA and beyond. For example, the sedge *Juncus kraussii* subsp. *australiensis* occurs along the coast from east of Esperance to north of Shark Bay. Its seed is small and easily distributed by wetland birds that travel long distances. Long distance dispersal creates disjunct populations of the sedge in wetlands in what are effectively 'islands' of suitable habitat surrounded by a much drier landscape.[1]

  Other species rely on water to transport their seeds. For example, *Aponogeton hexatepalus* seeds germinate in the season they form and when water is present they can float to new locations[1] in a wetland or possibly to a different wetland. If the wetland is connected to 'upstream' wetlands, waterways or even drains, some influx of propagules is possible.

Understanding which of the wetland's species use these dispersal mechanisms can provide an understanding of the potential opportunities and timeframes for natural dispersal to occur.

Fire-responsive: plants which have seed pods that open, seeds that germinate, or epicormic buds or lignotubers that resprout in response to a fire event. Some of these responses are triggered by the chemicals produced in smoke during the fire event.

Carrying out assisted regeneration

The two main types of assisted regeneration are:

- managed fire to produce a mosaic of burnt and unburnt areas over time
- smoke and smoked water.

Managed fire

In some instances, fire could be used to promote conditions suitable for regeneration of native plants. Fire can potentially stimulate seed germination, reduce the impacts of weeds (if managed)[24] and encourage the regeneration of mixed age vegetation.[25] Using fire as an assisted regeneration technique for vegetation change events is complex, and must take into account factors such as frequency, season, intensity, pattern and post-fire environmental conditions, as well as legality. Its use can be controversial as it may cause as many problems as it can potentially address, including further damaging existing vegetation as well as destroying seed banks and encouraging more weeds.

Burning is a form of clearing (see 'Clearing of native vegetation' earlier in this topic for the definition of clearing). Where vegetation is proposed to be burnt and the purpose is not exempt, a clearing permit under the *Environmental Protection Act 1986* is required.

➤ For more information, see *A guide to burning under the native vegetation clearing provisions.*[26]

Smoke and smoked water

An alternative to fire is applying smoke or smoked water to the wetland environment to promote plant germination. Using smoke on wetland areas is a relatively non-invasive technique which can be applied fairly cheaply to areas with **fire-responsive** vegetation. Fire-responsive plants are species which have seed pods that open in response to the heat and drying effect of a fire, and/or seeds that have enhanced germination in response to the chemicals produced in smoke during a fire event.[27,28] The chemicals that encourage seed germination are encapsulated in smoke or contained within a water medium and applied directly to the vegetation or soil, avoiding the need for fire. Smoke and smoked water can greatly assist in the germination success of many native seeds, and if the technique is applied correctly can result in regeneration events.[27] Sites to be planted or direct seeded can also be prepared before planting with smoke or smoked water so that seedlings planted can benefit from smoke germination chemicals. Site preparation is described in more detail in the revegetation section of this topic.

➤ The Botanic Gardens and Parks Authority of Western Australia has pioneered much of the research into the application of the chemical in smoke responsible for seed germination. A range of scientific journal articles on the subject are listed on the website: www.bgpa.wa.gov.au.

➤ For further information on using smoked water see:

- Geographe Community Landcare Nursery website[29]
- Greening Australia's *Seed germination data sheet*[30]

Carrying out revegetation

There are three key revegetation techniques:

- brushing
- direct seeding
- planting.

Revegetation is a broad topic. Many techniques are in use, and much has been written about it. When reading such literature, remember that revegetation occurs across many different ecosystems for many different reasons. The following is a very quick overview of key considerations for the purposes stated in this topic.

Brushing

Brushing involves harvesting seed-bearing branches of local plants (either during seeding season, or at any time for plants that hold their seed within their canopy in woody fruits) and laying these branches in chosen regeneration areas. When branches from shrubs and trees from genera such as *Melaleuca, Eucalyptus*, *Casuarina*, *Agonis*, *Astartea*, *Pericalymma* and *Banksia* are laid out, they drop seeds when the branch dries out, increasing the number of seeds present, and the woody material and leaf litter from the branches suppress emergent weeds and protect the regenerating seedlings from other degrading processes such as erosion or strong winds. Brushing is often applied in bare areas where weed control or slashing has occurred and the site requires protection while the brushed species have a chance to regenerate over time when conditions are most suitable.

Plant materials, such as stems, can harbour the pathogen *Phytophthora*, which causes the devastating Phytophthora dieback. It is essential that all brushing materials be carefully selected to avoid spreading Phytophthora dieback. A site assessment by a professional dieback assessor may be appropriate.

It is also important to ensure that the sourcing of brushing material be done carefully and sensitively, so as to minimise environmental impact. The taking of flora, including seeds, flowers, stems and all other parts of native plants, is regulated under the *Wildlife Conservation Act 1950*. On Crown land, taking of flora for any purpose requires a licence. On private property, the taking of flora needs to be authorised by the land owner, and a licence under that Act is only required if the flora is taken for sale. For further information on flora licences, contact DEC.

Clearing of native vegetation is regulated under the *Environmental Protection Act 1986*. Clearing that is done in accordance with a licence issued by DEC under the *Wildlife Conservation Act 1950* does not require a clearing permit.[31] Furthermore, the definition of 'clearing' under the *Environmental Protection Act 1986* does not include the taking of plant material where it does not cause any substantial damage to the plant. Thus, the careful and selective cutting of brush material (or the collecting of seed) should not require a clearing permit under the *Environmental Protection Act 1986*. Making use of plant material cleared for firebreaks or access tracks is also a good way to minimise impacts.

➤ For more information, see the following information sources:

- disease hygiene standards: the topic 'Phytophthora dieback' in Chapter 3
- regulations: see the text box 'Clearing of native vegetation' earlier in this topic

Direct seeding

Direct seeding involves placing viable seeds into a wetland and promoting their germination. The success of direct seeding relies upon appropriate seed collection, storage and preparation to maximise viability and germination success[32], site preparation and sowing. These last two factors are discussed in greater detail in the 'Revegetation' section of this topic.

Seed may be applied directly as cleaned seed that has been tested and, if appropriate, treated to achieve a pre-determined germination rate for the establishment of defined vegetation species composition and density. Alternatively, seed may be applied through indirect means, such as brushing (see above), or through the spreading of weed-free topsoil (applicable in dryland environments, such as areas surrounding wetlands).

Direct seeding can be suitable in weed-free areas of wetlands, although not on steep slopes if erosion is a risk. However, although direct seeding may be significantly cheaper than planting seedlings, it has had a mixed success rate in WA and in particular on the Swan Coastal Plain (the coastal area from Jurien – Dunsborough), due to a variety of reasons, including unsuitable approaches and site preparation.[33] Direct seeding success stories overwhelmingly involve adequate site preparation and post-seeding site management such as weed control, to allow the seedlings to germinate in the absence of other threats.[34] In many instances, although the process appears cheap, the outcomes are too poor to warrant the effort or resources invested. This is most often due to a lack of understanding about WA growing conditions in individual wetland environments, such as challenging soils and weather conditions. Other challenges include low seed viability and seed predation by birds, ants and other animals.[5] Because many of these factors cannot be controlled, wetland managers should compare opportunities for seeding activities with other methods of revegetation prior to commencement.

Seeding may also be used in conjunction with planting, to provide the opportunity for greater species diversity and natural plant establishment outcomes, while not relying only on effective seed germination and establishment for revegetation success. It is also important to note that seed sown may remain dormant for a number of years before germinating, achieving positive revegetation outcomes over a longer time frame.

Where it is important to determine the likelihood of success prior to proceeding with large-scale direct seeding, one possible approach is to trial the use of direct-seeding on a smaller scale.

➤ Many, but not all, native plants have successfully been direct seeded. For further information about direct seeding and types of species which can be direct seeded, refer to:

- the *Seed Notes for Western Australia*[35], which provide information on individual species as well as licensing and storage www.dec.wa.gov.au/content/view/3303/1808/
- *Florabank*, www.florabank.org.au, an information internet portal providing knowledge from research and practice in native species seed management for native seed suppliers, buyers, landholders and other NRM stakeholders

There are different ways to sow seed, including hand planting, niche seeding, broadcasting, machine planting and hydromulching. Many of these will not be appropriate in relatively intact wetland areas. Pre-seeded matting is excellent for steep embankments, providing both erosion control and seeds together. Seeds are spread onto an appropriate fibremulch and germinated. The seeding can occur in a nursery or on-site. If done at a nursery, it is only suitable for seeding of sedges and other monocots because the matting needs to be rolled up to transport (like roll-on lawn) to the site.[18]

Treating seeds prior to or following sowing can be very beneficial. The seeds of different species respond to different treatments, including smoke and smoke products, acid, cold stratification and heat. Seed suppliers often provide these treatment services.

➤ The range of direct seeding methods and seed treatments are outlined in Florabank, along with references for more details. See www.florabank.org.au> Seed Knowledge> Native Vegetation Management Tool> Direct seeding.

Planting

Planting techniques include:

- planting seedlings grown in seedling trays or tube stock
- strip or mat planting, useful in highly erosive sites and where there is the potential for waterbirds to pull plants out of the ground
- long-stem planting, where seedlings are grown to a height of 1 metre or more, and three quarters of the length of the plant is buried. (www.environment.nsw.gov.au/resources/grants/Longstemguide.pdf)

Preparing or pre-ordering stock from an accredited supplier in due time is essential. Collecting, treating and sowing seed of local provenance is a lengthy process which needs to be factored in to the works schedule. As a guide, standard tubestock of trees and shrubs should be no more than 7–8 months old, while sedges should be 10 months old.[18] At this age, tubestock should develop extensive root systems when planted and sedges will be engaged in lateral spread rather than vertical extension only, enabling rapid coverage of planted areas.[18]

Hand planting equipment includes trowels, spades, tree spades, mattocks, powered augers, pottiputkis, Hamilton treeplanters and Hamjam borers.[8] A range of mechanical equipment has been developed and is commercially available, but these are often not suitable for use in sensitive wetland sites.

Poor planting techniques by untrained volunteers can lead to poor establishment and higher mortality rates in seedlings. A short demonstration prior to the commencement of planting at volunteer days can put everyone at ease and reduce this potential problem.

Waterbirds such as ducks, coots, swans and occasionally herons can uproot sedges and consume submerged plants before they have established, quickly undoing lots of painstaking work. A trial exercise may help to determine whether it is likely to pose a problem at a site. Strip or mat planting can help reduce waterbird damage by weighting plants down. Bird netting may be warranted for large sites where waterbird damage is a known problem. For small-scale plantings, wire enclosures can be used for the first few months until plant roots are well established.[18] In both cases, the materials need to selected and installed with great care to ensure that there is no inadvertent injury or death to animals or humans.

➤ For more information on planting techniques, see:

- Florabank: www.florabank.org.au> Seed Knowledge> Native Vegetation Management Tool> Tubestock planting.
- *Revegetation techniques: a guide for establishing native vegetation in Victoria*[36] at: http://live.greeningaustralia.org.au/nativevegetation/pages/pdf/Authors%20C/13_Corr.pdf

Common problems

Some of the most common problems encountered by people revegetating wetlands include:

- not reducing the weed load before planting and not being prepared for follow-up weeding over long timeframes
- not factoring in enough time to get seeds/seedlings ready in time for planting
- planting at the wrong time of the year, or there being unpredictable weather
- underestimating the mortality rate of plantings, and overestimating the success rate of direct seeding
- seedlings being planted badly because people planting are unfamiliar with the procedure
- waterbirds such as ducks, coots, swans and occasionally herons uprooting sedges and consuming submerged plants
- vandalism, often by children

Some tips on these problems are outlined in the sections below.

Revegetation: key considerations

There are a number of details to consider when revegetating, including species choice, diversity and provenance. Timing of replanting activities, costs and post-planting maintenance are also key considerations.

When seeking to emulate the pre-vegetation change environment, the main considerations are:

- site preparation
- hygiene practices to avoid introducing weeds and diseases
- avoiding impacts to animals
- choosing the most suitable species
- aiming for original species diversity and density
- planting in the most appropriate locations
- deciding on the planting density
- minimising excessive damage to existing wetland values;
- using additives to soils during planting or seeding
- post-planting or seeding maintenance.

Site preparation

Preparing an area for replanting or direct seeding is an important step in ensuring revegetation success. Prior to both seeding and planting, the site should be cleared of weeds, as weed species will compete with natives for space and light.[37] The location, size of the area, amount of weeds to be controlled and rate of control should be dictated by the resources available and the rate at which revegetation is expected to occur following the removal of weeds. The Bradley method[16] is effective, that is, working from more

Figure 14. Arum lily (Zan*tedeschia aethiopica*) has taken over this area following the removal of bracken (Pteridium *esculentum*). Photo - J Nichol/DEC.

intact areas of vegetation towards more degraded areas. This allows natural regenerative processes within the environment to assist with regeneration and revegetation. Doing the job right to begin with saves considerable time and resources; managing weeds amongst seedlings can be time consuming and difficult.

If there is a diverse assemblage of weeds on site, or persistent weed vectors, it may take a number of years to eradicate or control them to levels suitable to undertake planting. Just as there is natural succession in native species, the same can be true of weeds. Removing one suite of weeds may just result in suitable conditions for another (Figure 14). It may take a number of years to eradicate or control weeds to levels suitable to undertake planting. Post-seeding and planting weed control is also critical.

➤ Weed control techniques for WA wetlands are described in the topic 'Wetland weeds' in Chapter 3.

Preparing the ground is an aspect of site preparation where particular care needs to be taken in relation to wetlands. Many techniques, such as deep ripping, furrowing and mounding are appropriate for paddocks being rehabilitated and in farm forestry sites, but are generally not appropriate in wetlands due to their impact on wetland soil.

Revegetation hygiene practices: weed and disease free seeds, plants and propagules, vehicles and equipment

It is critical to take steps to avoid introducing pathogens that cause disease and weeds. For example, Phytophthora dieback, which is caused by *Phytophthora* species, can have devastating effects on the vegetation of wetlands and surrounding dryland. *Phytophthora cinnamomi*, for example, can be brought into a site in infected soil, water and plant materials (including dead plant material such as bark and mulch).

It is essential that hygiene standards be observed in all aspects of revegetation programs to minimise the spread of weeds and Phytophthora dieback.

➤ For more information, see the topic 'Phytophthora dieback' in Chapter 3.

Avoiding impacts to animals

Planting disturbs the soil. It is important to consider that animals, or their eggs, may be present in the soil, including burrowing crayfish, frogs (Figure 15), turtles, and a wide range of small invertebrates. It is also important to consider the impact that soil disturbance may have on water quality, and how this may affect species that are sensitive to turbid conditions or to being covered in sediment. For example, fine particulate matter suspended in water can affect many aquatic species, including fish, by clogging, coating or abrading respiratory structures such as gills.

➤ For more information on wetland animals, see the topic 'Wetland ecology' in Chapter 2.

Figure 15. The burrow of a white-bellied frog (*Geocrinia alba*), a critically endangered frog, is susceptible to soil disturbance. Photo - K Williams/DEC.

Species diversity

When seeking to emulate the vegetation that was present prior to a vegetation change, species diversity will be an important consideration. Unless the wetland had a low diversity or the vegetation was well documented, determining the diversity prior to vegetation change event can be a difficult task. Photographs and aerial photographs can provide insight; if this information isn't available it may be useful to examine a nearby wetland of the same or similar type.

Some wetlands naturally support a low diversity of native vegetation. For example:

- some primary saline wetlands
- some wetlands with an overstorey that has a closed canopy and a dense leaf litter
- permanently inundated areas with deep water
- those where benthic microbial communities are prevalent

In situations where the original species will no longer survive, it is necessary to choose an alternative suite of species. This may be necessary when a wetland:

- has become more saline, such that plants with a greater salt-tolerance are necessary. Freshwater wetlands generally have a higher diversity of species than those of saline wetlands.[1]
- is infected with a pathogen such as *Phytophthora cinnamomi*, such that Phytophthora dieback resistant plants are necessary. As over 40 per cent of native plants in south-west WA are susceptible[39], this is likely to limit species diversity.
- has a significantly altered hydrology, such that plants with different water requirements are necessary. This is less likely to alter species diversity.

Provenance: the place of origin[42]

Figure 16. A simple planting regime with low diversity of species may be justifiable in some circumstances, particularly where it is intended to continue the rehabilitation over time. Photo – DEC.

- the water quality is significantly altered, such that tolerant plants are necessary. Some plant species are known for having greater tolerance to higher nutrient levels or for their ability to remove excess nutrients, such as lake club-rush (*Schoenoplectus validus*), salt rush (*Juncus kraussii* subsp. *australiensis*) and tall spikerush (*Eleocharis sphacelata*).[16]

When considering the introduction of locally native species that were not present in the wetland prior to the vegetation change, it is important to ensure that the benefits of their introduction are greater than potential disadvantages (e.g. weediness).

Another important consideration is that not all wetland plants can be supplied for use in revegetation projects, because many have not yet been successfully propagated (bred).

Other circumstances may also constrain the ability to achieve the original species diversity. In particular, the condition of a site may mean that the resources required to prepare the site, manage weeds and achieve the desired species diversity is beyond those available. In some highly degraded sites that have been determined to be a priority for revegetation, it may be necessary to begin with a simple planting regime (Figure 16) to initiate the rehabilitation of the site, within the scope of the available resources.

Plant choice: provenance and ecotype

When seeking to emulate the vegetation that was present prior to a vegetation change, wetland managers will be sourcing seeds or seedlings of the species that were present. However, it is important to take this a step further by sourcing seeds and other propagules (seeds, seed inundated mud or sediments, plant cuttings, plant roots or rhizomes[19,40]) of local **provenance**, that is, local origin. A species' genetic variation over a geographic range can reflect the ecological conditions in which the species has evolved. A compelling reason for ensuring local provenance of propagules is that in WA the genetic variation within plant species can change over short distances, meaning that the wetland itself is the best choice to source propagules, followed by wetlands as geographically close to it as possible.[41] Recent research indicates there are some circumstances when it may be beneficial to broaden the provenance for revegetation activities, for example, when there is a need to build in greater tolerance in the vegetation to cope with environmental changes; these should be considered on a case-by-case basis. For more information, see www.florabank.org.au> Seed Knowledge> Native Vegetation Management Tool> Design – Species and provenance selection.

Many wetland plants have closely related species that inhabit dryland. Furthermore, many taxa have distinctive wetland and dryland **ecotypes**, and a number of these ecotypes are proving to be valid discrete taxa. Correct ecotype is an important consideration.[2]

Care should be taken during collection of genetic materials from local intact wetlands to not cause further damage to these wetlands by taking too much.[19] To prevent damage, seed collection and harvesting of plant genetic material is regulated in WA. Collections must be made in a manner that protects existing plants, with only limited materials being taken. The taking of smaller quantities of propagating material from a greater number of plants also increases the genetic diversity of material being used for revegetation, thereby increasing the health and diversity of the vegetation being established.

Revegetation practitioners must also have permission to collect plant material from land managers prior to any site visit, and should ensure that all collection sites are protected from damage caused by collecting activities.[32,40] Particular care needs to be taken to prevent spread of plant diseases and incidental destruction of vegetation by vehicular movement.

The laws governing flora conservation are contained within the *Wildlife Conservation Act 1950* and Regulations. These are administered by DEC. Flora is protected and may or may not be able to be harvested under particular conditions relating to the level of protection required. Licenses are required for collection on Crown land and the commercial use of flora, and different licenses exist depending on the purposes for collection. Permission is also required from the land manager, including for private property.

➤ For specific information on the details for licensing and laws surrounding flora collection, please go to the flora licensing webpage[43] on DEC's website: www.dec.wa.gov.au/management-and-protection/plants/flora-licensing.html

➤ The Revegetation Industry Association of WA (Inc)[44] has information on seed collection: www.riawa.com.au

It is estimated that tens of thousands of sedges have been used in revegetation projects in wetlands in the Perth region that have been propagated by tissue culture, often used without reference to provenance and with extremely narrow genetic diversity due to using a small number of clones.[45] However, it has been demonstrated that it is possible and relatively easy to produce large numbers of some WA sedges from seed and in doing so maintaining genetic diversity.[45]

Planting and seeding in the right spot

Plant germination and survival depends upon a range of factors, such as **water regime**, soil wetness, salinity, pH, temperature, light, nutrients and competition.[15] These factors vary over time and space. That is, they change with seasons and shorter and longer term drivers; and they change over a geographic area.

Identifying the optimal establishment zone of a plant should take into account the most important factors. Water regime is particularly variable within a wetland and this factor is a strong determinant of where a plant would naturally germinate. If the water regime is intact, planting replacement vegetation becomes more straightforward as seeds or plants can be located where they were previously found.

This approach accounts for the water requirements of species. Even a basic understanding of a plant's **water requirements** will help. Knowing whether a plant is always, sometimes or never submerged under water is a good start. If it is sometimes submerged, knowing the minimum and maximum inundation it can tolerate is important. If it is never submerged, knowing its tolerance to waterlogging and completely dry soil is critical.

Ecotype: a genetically distinct geographic variety, population or race within a species which is adapted to specific environmental conditions. Typically ecotypes exhibit differences in morphology or physiology stemming from this adaptation, but are still capable of breeding with adjacent ecotypes without loss of fertility or vigour.

Water regime: the pattern of when, where and to what extent water is present in a wetland. The components of water regime are the timing, duration, frequency, extent and depth, and variability of water presence

Water requirements: the water required by a species, in terms of when, where and how much water it needs, including timing, duration, frequency, extent, depth and variability of water presence

Figure 17 below provides an example of the vegetation of a wetland that is permanently inundated, showing a classic series of plant types from the centre of the basin to the outer extent of the seasonally waterlogged area of the wetland. The series of plant types, from submerged to emergent plants, occur in zones. This diagram is an example only; there are many patterns of diversity and structure of vegetation in wetlands, including many which do not support classic zonation, for example, as shown in Figure 2 and Figure 3. For example, a seasonally inundated basin wetland may have less aquatic plants and more fringing vegetation than a wetland with standing permanent water such as a lake. The vegetation patterning will therefore vary depending on the type of wetland, its water regime and historical impacts.

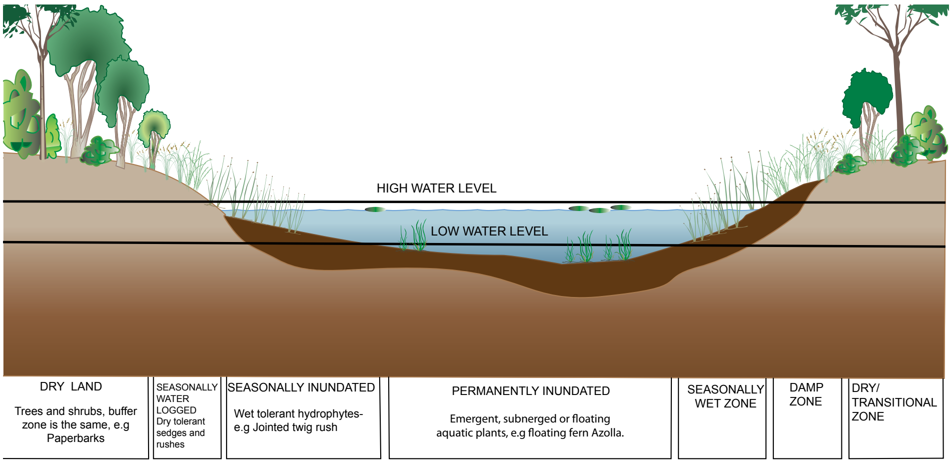

Figure 17. Zonation of plants in a permanently inundated wetland. Adapted from work by Denise Crosbie, Cockburn Wetlands Education Centre (2006).

In 2000, a study was carried out on the water levels and duration of inundation or waterlogging being experienced by sixty wetland species at wetlands on the Swan Coastal Plain.[46] The results of this study have been used to inform the management of a number of wetlands in the greater Perth area. For example, the common wetland tree *Melaleuca rhaphiophylla* was found, on average, to exist at a maximum water depth of 0.006 metres above the ground and minimum water depths of 2.14 metres below the ground. However, the maximum water depth at which the tree was found during the study was 1.03 metres, while the minimum water level at which it was found was 4.49 metres below the ground. It was found to live in wetlands that are inundated on average 2.15 months of every year, but the longest period was 9.4 months of every year. This information is useful in that it provides wetland managers with a coarse indication of the maximum and minimum thresholds for the species' survival. Of equal importance, it shows that there is a great deal of variation amongst a species. However, identifying the water regime that supports a species is not as simple as defining the extreme measures (maximum and minimum). Simply maintaining the water level between a maximum and minimum height is a simplistic approach, because variability in water level is important for plant reproduction and other aspects that determine the ecological character of the site. Since this study, further studies have been undertaken across the broader south-west, resulting in updates to this water range data. Studies have also been undertaken in other areas of the state, as listed below.

➤ Information on water requirements for planting include:

- *A guide to emergent wetland plants of south-western Australia*[47] is an excellent resource, providing a guide to the habitat location, optimum and maximum water depth and mean annual water level tolerated by thirteen native sedges, as well as their seasonal flooding range.

- *Water regime for wetland and floodplain plants: a source book for the Murray-Darling Basin*[48] is, as the name suggests, focused on eastern states species, but does describe the germination requirements of *Eucalyptus camaldulensis* in detail, as well as those of *Muehlenbeckia florulenta*, *Eragrostis australasica*, *Eleocharis acuta* and *E. sphacelata*, *Typha domingensis* and *Cyperus gymnocaulos*.
- Although more technical in nature, a range of water requirement studies of wetland plants may also be useful. In WA, research into the water requirements of wetland organisms has focused on the Gnangara and Jandakot groundwater mounds in the greater Perth region[46,49,50], the Blackwood and Scott Coastal Plain groundwater areas[51], and Ramsar wetlands. Riparian studies that include wetland species in the Pilbara and Kimberley have also been the subject of a number of studies (for example, Loomes[52,53,54]).
- *Establishing samphires in the Avon catchment*[55]

Even when optimally planted, the best efforts of a wetland manager can be confounded if exceptionally wet or dry conditions occur during the growing season – some death of plants is to be expected, although contingencies such as watering may assist in minimising plant losses.

Deciding on planting and seeding density

Replicating the original density can be informed by examining part of the site which has not experienced a vegetation change or by examining a nearby similar, intact wetland, often referred to as a 'benchmark' site.

Planting should attempt to mimic the natural environment as much as possible, but managers should be aware that planting in densities greater than 10 plants per square metre can be very costly and time consuming.

The natural density of wetland vegetation varies widely between wetlands, even those with similar characteristics or in close proximity to each other. This makes it difficult to provide even rules of thumb about appropriate planting densities. Denser is not always better, for example, bare patches between areas of vegetation are often important habitat for a range of reptiles.

Published rules of thumb/actual densities include:

- 2-3 seedlings per square metre in poor and very poor sites
- a rough guide of 500:50:5 herbs or sedges:shrubs:trees for each 100 square metres for riparian vegetation (that is, vegetation associated with waterways) in south-west WA[56,18]
- where only sedges and rushes are being used, a rate of 6-9 tubes or cells per square metre. More sedges/rushes per square metre can be used to achieve dense stands faster, if budgets allow. For a larger stock size, such as blocks or strips of sedges/rushes, densities are normally determined by site characteristics and budget constraints. The closer the blocks and strips are planted, the quicker they will grow to meet each other and create dense stands.
- for direct seeding, determine the seed viability, allow 50 per cent mortality of seedlings, and calculate the required seed lots accordingly (this service is available from some commercial seed operators).[18]

In the south-west of the state, as a rule of thumb, an average loss of up to 80 per cent of all germinants of direct-seeded trees and shrubs can be expected after two years, therefore seed should be sown at a rate of twenty germinable seeds per square metre.[18] The average mortality rate of planted trees and shrubs is estimated to be 30–50 per cent.[18] Over-seeding and over-planting (also known as saturation planting) is often used in anticipation that a certain percentage of the seeds or plants will not survive in the short to medium term. This technique has the added benefit of reducing the area available for weed establishment during the seedling establishment phase.

Timing of seeding and planting

Seeding

As a rule of thumb, seeding should occur prior to the main rains[56]) to give establishing plants the greatest period before drought stress occurs. This is roughly late summer/ early autumn in the south-west of WA, but can differ yearly. The wetland environment can hold water for longer periods than dryland areas, giving new plants a longer establishment period. However, in wetland environments it is important to be aware that surface water flows may wash away seeds. More intense rainfall events can also lead to inundation and poor seedling survival.

Planting

The optimal planting time can depend on the type of plant and whether it is to be planted into an area subject to inundation or waterlogging.

As a rule of thumb, in the tropical climate of northern WA, it is appropriate to plant at the start of the rains, in summer, when rainfall events are common and the soils are moist and yet still warm.

In the south-west of WA, the Mediterranean climate means that most plantings are ideally undertaken in late autumn, at the beginning of the rainfall season, when the soil is moist and still warm and more rain is to be expected. However, winter planting of waterlogged soils and the edges of inundated zones, and early summer planting of zones where inundation is giving way to waterlogging, has been found to work at some sites (for an example, see the case study 'Challenges in wetland rehabilitation at Bibra Lake' at the end of this topic). In inundated wetlands in the south-west of WA, many wetland sedges are planted in spring/summer when water levels are receding (if in the water column) Sedges may be dormant over winter and as a result their roots may not establish as well. This means they can be susceptible to damage by high-energy winter storm events that cause waves and erosion. Similarly they may not be tall enough to avoid being submerged, leading to death.

To water or not to water?

There are many opinions about whether or not to water seedlings in the dry seasons following their germination/planting. As outlined above, planting in the optimal establishment zone of a plant should minimise the need for watering. Over and above this, whether or not it is appropriate in a given situation depends on many factors including:

- seasonal rainfall variations
- soil conditions
- species chosen

Watering can influence the root development of a plant. If, as a seedling, the plant is watered often, it is less likely to establish deep roots to find water. When watering ceases, the plant will have less ability to find water for itself, and will lose vigour and may die unless it can develop a suitable root system.

Wetland managers may consider a limited period of watering, for example, over the first one or two summers, to encourage establishment and minimise potential plant death. In seasons with lower than normal rainfall watering is likely to be required to achieve acceptable plant establishment rates. Optimal watering is infrequent, deep watering, to encourage deep root systems, and watering the base of plants (the root zone) rather than its leaves or branches. Watering can be logistically challenging and expensive.

Soil improvers, fertilisers and plant guards

As a general rule, soil improvers and fertilisers should not be used in wetlands. Native plants have adapted over thousands of years to local soils, hydrology and climatic conditions. Many improvers and fertilisers contain nutrients in much higher amounts than can be tolerated by native species.

The application of gypsum, or dihydrous calcium sulphate ($CaSO_4 2H_2O$), is often suggested for clay or sodic soils to improve soil structure, such as sites subject to secondary salinity, which causes the soil structure to become compacted, and the growing environment for the local plants is changed. Gypsum addition will replace the sodium (Na) ions with calcium (Ca) ions which help to open the soil structure and improve soil permeability. However, this will only be effective in the longer term where the source of the salinity has been addressed and no further sodium is entering the wetland system. If this is not feasible, then the short term benefit and cost of gypsum addition is hard to justify.

The wetland origins of many soil conditioners

Gypsum, or dihydrous calcium sulphate ($CaSO_4 2H_2O$), is a natural product of many wetlands in WA, particularly in the Wheatbelt, the south-west and Goldfields region. Gypsum deposits in wetlands and in the dunes on the southern and south-eastern shores over time; it is estimated that deposits have been forming up to 35,000 years ago in some WA wetlands.[38] In WA it has been mined since 1921 using methods such as excavators (dry excavation) and sub-aqueous dredges. As well as being mined for use as soil conditioners, gypsum is mined for a multitude of uses, including drywalls, plasters, and fertilisers. Similarly, bentonite clay is mined from WA wetlands for use as a soil wetter as well as a range of other industrial and domestic applications.

Plant guards, such as those shown in Figure 18, can reduce grazing by animals such as rabbits, kangaroos and uprooting by waterfowl such as purple swamphens (*Porphyrio porphyrio*).[25] Guards can be costly and time consuming to install, and have limited benefit if not well maintained. Their use comes with the understanding that they will need to be manually removed, when plants are big enough, and if plastic like the ones shown below, generally prior to summer to prevent killing plants by overheating them (the use of mesh plant guards may minimise this issue).

Figure 18. a) plant guards can help to protect plants from people and other animals; b) unmanaged plant guards may stifle plants or result in over-heating. Photos - J Nichol/DEC.

Symbiosis: a condition in which two organisms live in a mutually beneficial partnership

Mycorrhiza: a symbiotic association between a fungus and the roots of a plant, from which both fungus and plant usually benefit

Timeframes

In natural wetland environments, plants interact with other physical, biological and chemical factors such as climate, soils and hydrology to grow, establish and undertake ecological function over long periods. How long it may take to revegetate a wetland and re-establish these processes is therefore a matter for consideration for wetland managers to manage projects and balance resource allocations.

Another factor to take into account when considering timeframes is the predicted numbers of plants surviving to adulthood following a revegetation project, based on natural attrition and the recognition that revegetation is an artificial process and plants will not always survive. Whilst detrimental vegetation change may occur in wetlands over short periods of time (1–5 years), it is widely recognised that ecological processes will not be reinstated within similar timeframes.

The role of fungi and lichen

Fungi are multi-celled organisms that are neither plants nor animals (fungi is the plural, fungus singular). Fungi include an extremely wide range of organisms including macrofungi such as mushrooms, toadstools, puffballs, coral fungi, earthstars and truffles, and an even broader range of microfungi.

Fungi occur in most environments, however, some fungi species are much more prevalent in wetlands than other areas, such as certain species of macrofungi that fruit most abundantly on paperbark (*Melaleuca*) trees, and the predominantly microscopic aquatic fungi, which rely on free water for some part of their life cycle.

Studies worldwide show that a large number of wetland plants are partnered with mycorrhizal fungi[57,58] and WA is no exception—including but not limited to *Melaleuca, Astartea, Isoetes, Cotula, Viminaria, Myriophyllum, Nymphoides, Nymphaea, Pericalymma, Livistona, Pandanus, Ruppia* and *Eucalyptus*.[59] In recent decades there has been developments in the understanding of mycorrhizal associations with sedges, and the major role they play in phosphorus dynamics.[58]

Many fungi form a close association with plants in which both parties benefit (**symbiosis**) from an exchange of nutrients and sugars. This relationship is known as **mycorrhiza** and the roots of the associated plants are referred to as mycorrhizal roots. These mycorrhizal roots are connected to networks of microscopic thread-like structures developed by the fungi known as hyphae or mycelia, which explore and exploit a far greater area of the soil than uncolonised roots alone. These networks take up nutrients, such as phosphorus, and transport the nutrients back to the plant. Two main types of mycorrhiza occur: endomycorrhiza, where the fungi penetrate the plant's cell wall, and ectomycorrhiza, where the fungi are external to the plant cells. Endomycorrhiza are formed mainly by microfungi and can be present in permanently flooded soils, while ectomycorrhiza are formed by many macrofungi and appear to be sensitive to inundation.[60]

The significance of these beneficial plant-fungi partnerships needs to be considered when planning wetland revegetation. Research has found that healthy natural woodlands have a greater diversity of native fungi than degraded woodlands or revegetated agricultural lands, and that most native fungi are not self re-establishing in degraded or cultivated land, at least in the short to medium term.[61] Mycorrhizal fungi suitable for some plant species is now being made available by commercial suppliers. These fungi are mostly applicable to a range of non-woody plants. Inoculum specifically for use in revegetation for many natural Australian ecosystems with woody plants is not available. Inoculum obtained from similar vegetation in the local area is considered likely to be the most suitable. For more information, see the fungi information in the topic 'Wetland ecology' in Chapter 2, which provides a list of sources of additional information.

Lichen, cyanobacteria, bryophytes, mosses and liverworts form biological soil crusts. These crusts can help to reduce erosion, control water flow through soils, enhance soil nutrition and provide niches for plant seedlings and invertebrates.[62]

Inappropriate management techniques

Care should be taken when undertaking revegetation activities to ensure that the act of revegetation itself does not adversely impact on the condition of the wetland.

Some potential adverse impacts of wetland vegetation management include:

- planting or seeding when natural regeneration is possible. Trampling, weed spread, plant loss, soil compaction and introduction or spread of disease are all risks brought to bear unnecessarily.
- removing dead trees, logs and leaf litter, as these still function as habitat for native plants, animals, fungi, lichen and bacteria. Over time they are broken down and their nutrients are recycled.

case study

Restoring vegetation: the importance of weed control over the long term

John Lombardo was resigned to weeds and dying plants on his private property of 3 hectares in Wandi, thirty-two kilometres south of Perth. Over fifteen years, John had observed the wetland becoming increasingly infested with weeds such as arum lily (*Zantedeschia aethiopica*), perennial veldt grass (*Erharta calycina*) and Sydney golden wattle (*Acacia longifolia*). These weeds were causing composition changes in the wetland, displacing native plants.

In 2005, WWF agreed to fund some work on the property over a three year period, via its 'Wetland Watch' program. The project included the preparation and implementation of a management plan. Implementation included funding for controlling weeds, undertaking minor revegetation and controlling rabbits to allow regenerating plants to establish.

Management strategies - weed, plant and weed again

For the next four years, John undertook a number of weed control and assisted regeneration activities to improve the condition of the wetland vegetation. Specific wetland weeds were targeted for reduction or eradication. The herbicide Fluazifop-p-butyl (the active ingredient in 'Fusilade'), was sprayed over the entire site for several years to target non-native grasses without damaging the existing sedges, rushes and other natives. This controlled the veldt grass and paspalum (*Paspalum dilatatum*). Arum lilies on the property were also treated using other targeted herbicides and woody weeds such as the Sydney golden wattle were hand-removed.

Rabbits were controlled on site by baiting with Pindone. The baiting control was successful for several years in reducing the rabbit populations. However, the rabbits did return, so plant guards were placed around all new planted seedlings. Over time and with perseverance, the wetland began to naturally regenerate, with rushes and sedges growing from existing areas and seedlings of *Kunzea* and *Astartea* springing up once the areas were cleared of weeds (Figure 19, Figure 20).

Ongoing weed monitoring and management

The wetland now has more diversity of wetland species, which John regularly monitors when making his daily walk around the paths (Figure 21). During these walks, John observes any emergent woody weeds such as the Sydney golden wattle and removes the seedlings on the spot. Frequent, short visits to see changes and notice if weeds are spreading is a good technique to ensure work is achieved with limited time allocated. This method is labour intensive, however, John considers the success of the regeneration is well worth the ongoing management.

case study

Figure 19. Natural regeneration of *Casuarina* sp. following consistent weed control and other assisted regeneration activities. Photo - J Nichol/DEC.

Figure 20. Natural regeneration of sedges following consistent weed control and other assisted regeneration activities. Photo - J Nichol/DEC.

John also uses his daily walks in summer to assess whether or not he should water some of the revegetation sites he is working in. John calls his watering frequency "summer rain", in that he only puts around 20 millimetres of water on the wetland areas infrequently, no more than once a month, so as not to cause weeds to germinate or increase the spread of plant disease. John has noticed the plants in these areas do survive the hot summer conditions better.

Ongoing maintenance and monitoring

John's wetland continues to slowly regenerate, following his regime of controlling grasses two to three times per year, annual arum lily control and ongoing woody weed management. He has turned areas from old tracks to stands of *Melaleuca*, *Kunzea* and *Astartea*. Whilst the work is labour intensive the site is small enough to be managed with John and his wife undertaking limited tasks once or twice a week, breaking down the workload into manageable amounts and areas. John hopes to carry out more weed control and management in the future, and looks forward to the return of more native flora and fauna, such as blue wrens (*Malurus cyaneus*), at his property.

Figure 21. Mr John Lombardo showing regeneration on his property in Wandi. Photo - J Nichol/DEC.

PLANNING VEGETATION MANAGEMENT

Planning for vegetation management can be logistically challenging. It often involves long timeframes, overlapping tasks, and substantial resources. A schedule of works is a good way to structure tasks and understand timeframes, and should take into account all of the below factors.

Climatic variations, inferior seeds, incorrect planting methods, storm events, flooding, drought, weeds or varied water quality parameters are just some of the unpredictable influences which will affect the outcomes of a revegetation activity, yet many revegetation projects do not account for these factors. For example, in natural wetlands, native plant seeds may lay dormant within the sediment for years or even decades before the right combination of physical and chemical conditions for germination occur. Yet many projects are planned with the expectation that an entire area will be revegetated in only a few years, without any allowances for the unpredictability of nature. Planning for a project, and measuring its success, needs a timeframe of several years rather than months.

Wetland managers should therefore recognise the complexity of such a task during goal and objective setting, and resource allocation, in order to more accurately predict how long a revegetation project may take, and what will constitute a 'success'.

Planning should account for plant deaths through natural attrition and other causes. Undertaking strategic management activities like overplanting or using several techniques at once, such as direct seeding and revegetation may help reduce the potential for setting unrealistic expectations. Managers should always remember that revegetation is merely a tool used for managing wetlands which are too degraded to regenerate naturally and that success may need to be measured after a long period of time to measure if wetland processes have been restored as a result of the revegetation.

Ideally, wetland management should form part of an overall wetland management plan. A plan can identify priority wetland management actions and where, when and how these should be undertaken.

➤ A process for wetland management planning is described in the topic 'Wetland management planning' in Chapter 1.

Contingency planning

The planning process may identify collecting and storing seeds or other plant propagules as a suitable contingency action, particularly if there is a high risk to the wetland vegetation, or if individual species are rare or difficult to harvest. Seed storage facilities are provided by revegetation businesses companies and a number of non-government conservation organisations.

case study

Challenges in wetland rehabilitation at Bibra Lake

Adapted from a case study prepared by Denise Crosbie (Cockburn Wetlands Education Centre) and Norm Godfrey (Wetlands Conservation Society)

Bibra Lake is a permanently inundated wetland in Perth's southern suburbs. Extensive weeding and planting has been carried out in Bibra Lake.

Getting started

The inundated area of Bibra Lake fluctuates from season to season and year to year. Different wetland plants and weeds are associated with different zones in the wetland, and this has implications for rehabilitation activities. Maps were prepared to gain a better understanding of the site conditions including water levels, topography, type and extent of existing native vegetation and weeds. Weed control was then planned and implemented and planting initiated.

Trials and tribulations

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

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

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

Revegetation

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

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

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

case study

Figure 22. The site post-spraying, being prepared for planting. Photo – D Crosbie/Cockburn Wetlands Education Centre.

Figure 23. Seedlings were planted with tree guards and weed mats to combat weed regrowth. Photo – D Crosbie/ Cockburn Wetlands Education Centre.

case study

Figure 24. Secondary weed growth – weed regrowth was less where mulch had been applied. Photo – D Crosbie/ Cockburn Wetlands Education Centre.

Figure 25. The site two years later following planting. Photo – D Crosbie/Cockburn Wetlands Education Centre.

case study

So, can we really bring back the understorey?

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

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

GLOSSARY

Adaptation: the process by which an organism becomes fitted to its environment

Biomass: the total mass of biological material (living or dead), usually expressed as live or dry weight per unit area or volume

Bradley method: working from the most intact parts of a bushland area out towards more degraded areas, to allow natural regeneration to occur, for example, when weeding

Clearing: any act that kills, removes or substantial damages native vegetation in an area. This includes severing or ringbarking of trunks or stems, draining or flooding of land, burning of vegetation and grazing of stock or any other act or activity that causes damage to some or all of the native vegetation in an area

Community: a general term applied to any grouping of populations of different organisms found living together in a particular environment

Dynamic: a process or system which is characterised by constant change or activity

Ecological community: naturally occurring biological assemblages that occur in a particular type of habitat

Ecological character: the sum of a wetland's biotic and abiotic components, functions, drivers and processes, as well as the threatening processes occurring in the wetland, catchment and region

Ecological linkage: a network of native vegetation that maintains some ecological functions of natural areas and counters the effects of habitat fragmentation[oo]; a series of (both contiguous and non-contiguous) patches of native vegetation which, by virtue of their proximity to each other, act as stepping stones of habitat which facilitate the maintenance of ecological processes and the movement of organisms within, and across, a landscape[7]

Ecosystem: a community of interdependent organisms together with their non-living environment

Ecotype: a genetically distinct geographic variety, population or race within a species which is adapted to specific environmental conditions. Typically ecotypes exhibit differences in morphology or physiology stemming from this adaptation, but are still capable of breeding with adjacent ecotypes without loss of fertility or vigour.

Endemic: naturally occurring only in a restricted geographic area

Eutrophication: the nutrient enrichment of a water body, which can trigger prolific growth of plant material (phytoplankton, macrophytes or both). May occur naturally over geological time or may be human-induced.

Fire-responsive: plants which have seed pods that open, seeds that germinate, or epicormic buds or lignotubers that resprout in response to a fire event. Some of these responses are triggered by the chemicals produced in smoke during the fire event.

Functioning ecosystem: a community of interdependent organisms together with their non-living environment. A functioning ecosystem is one which has a full suite of these normal resources and functions successfully, interacting within an ecosystem all of the time to maintain a stable sustainable system over time.

Mycorrhiza: a symbiotic association between a fungus and the roots of a plant, from which both fungus and plant usually benefit

Propagate: grow plant specimens from parent material

Propagule (plant): any part of a plant from which a new plant can grow, including seeds, bulbs and rootstocks

Provenance: the place of origin[42]

Recruitment: addition of new individuals to a population (usually through reproduction)

Reference wetland: a wetland used to provide a model for planning a management project

Rehabilitation: the re-establishment of ecological attributes in a damaged ecological community although the community will remain modified

Resilience: capacity of a system to absorb disturbance and reorganise while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks

Restoration: returning an ecological community to its pre-disturbance or natural state in terms of abiotic conditions, community structure and species composition

Revegetation: return vegetation (indigenous or otherwise) to an area

Senescence: the natural aging and subsequent death of an organism

Succession: progressive change in species composition and/or structure that occurs following disturbance of a site

Symbiosis: a condition in which two organisms live in a mutually beneficial partnership

Taxa: a taxonomic group (the singular being taxon). Depending on the context, this may be a species or their subdivisions (subspecies, varieties etc), genus or higher group

Threatening process: processes that threaten the survival, abundance or evolutionary development of a native species or ecological community

Thresholds: points at which a marked effect or change occurs

Turbid: the cloudy appearance of water due to suspended material

Vegetation: combinations of plant species within a given area, and the nature and extent of each area

Water regime: the pattern of when, where and to what extent water is present in a wetland. The components of water regime are the timing, duration, frequency, extent and depth, and variability of water presence

Water requirements: the water required by a species, in terms of when, where and how much water it needs, including timing, duration, frequency, extent, depth and variability of water presence

Wetland buffer: an interface adjoining a wetland that is designated to assist in protecting the wetland's natural values from the threats posed by the surrounding land use(s)

Wetland processes: the dynamic physical, chemical and biological forces within a wetland, including interactions that occur between wetland organisms, within the physical/chemical environment, and interactions of these

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