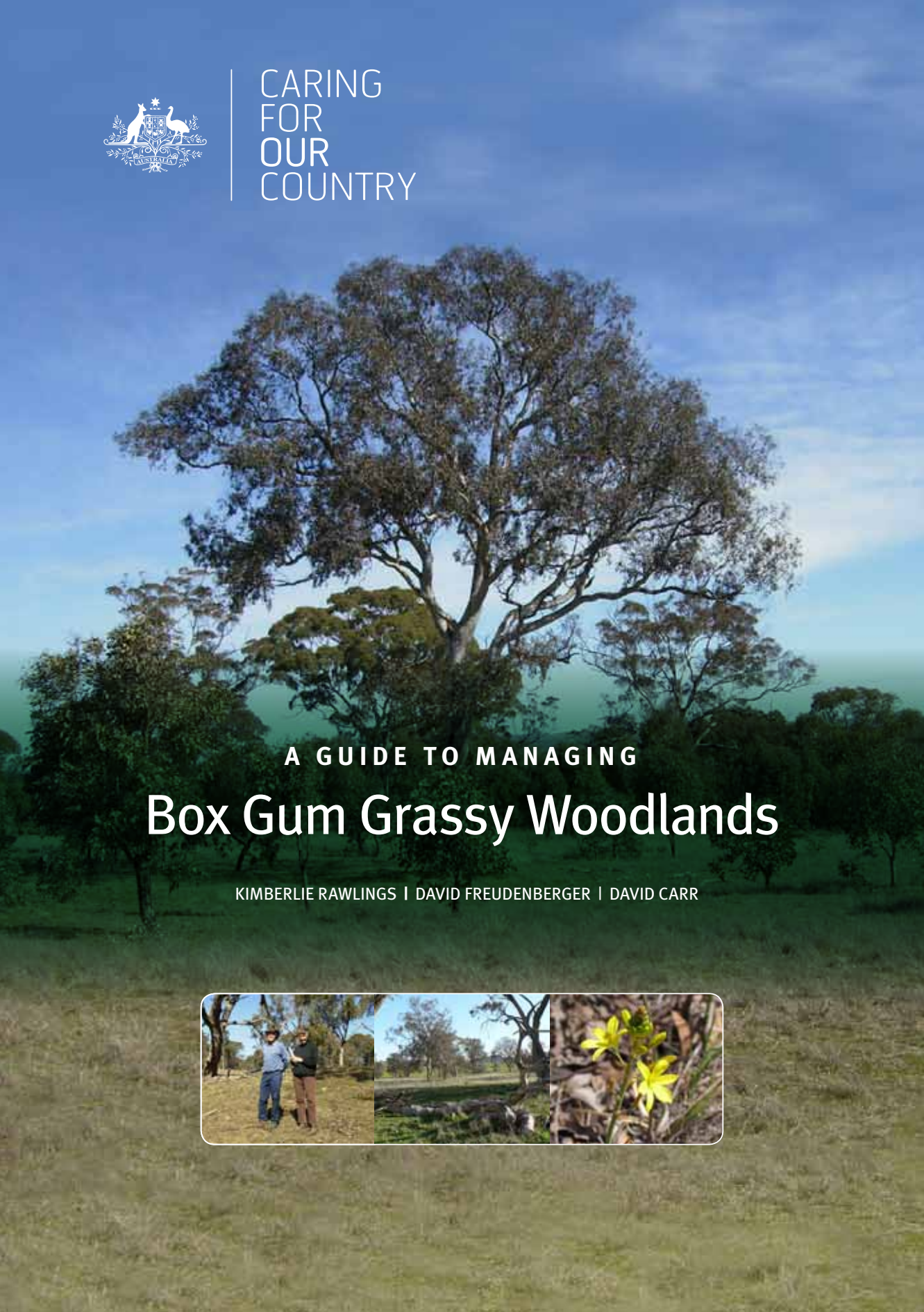
CARING FOR OUR COUNTRY



A GUIDE TO MANAGING

Box Gum Grassy Woodlands

KIMBERLIE RAWLINGS | DAVID FREUDENBERGER | DAVID CARR

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CARING FOR OUR COUNTRY

Preface

This handbook is designed to assist private land managers. It will particularly help those contracted through the Environmental Stewardship Box Gum Grassy Woodland Project to improve the amount and condition of box gum grassy woodland on their properties. It focuses on elements specific to the project, which include:

- the State and Transition Model for box gum grassy woodlands
- required and optional management activities
- monitoring guidelines for Environmental Stewardship contract holders.

The handbook covers the underpinning science and management requirements of box gum grassy woodlands. Because it is not limited by the quality of the woodland remnants, it will help contracted land managers go beyond their contractual obligations. This handbook should also assist those who are not part of the Project, but who are considering how best to manage box gum grassy woodland remnants on their property. It provides an understanding of how these woodlands work, how they can fall apart and importantly, how they can be repaired.

Throughout the book there are practical case studies that demonstrate how people are managing and conserving box gum grassy woodlands. The case studies come from farms, research sites and protected areas that cover the range of the box gum grassy woodlands region. The case studies are used to:

- provide examples of key ecological concepts
- provide photos of ideas or techniques that are otherwise difficult to convey
- demonstrate some interesting management approaches that farmers are using, including some of their failures.

As the case studies are snapshots of a particular property or management approach, they should not be taken as a prescription for your box gum grassy woodlands.

The common names for plant and animal species have been used throughout the book, with the scientific name given where that species is first mentioned. A full list of plant species mentioned in the handbook, as well as several others associated with box gum grassy woodlands, appears in Appendix A.

This handbook uses a numbered referencing system. A small superscript number corresponds to a numbered book, paper or website listed in the 'References' section at the end of *Part III: Management*. These references provide the scientific support for the statements made in the text. For example, the following sentence has been pulled from Chapter 4: The ancient soils under most grassy woodlands are naturally low in fertility [55]. The superscript number 55 corresponds to the 55th reference in the reference list:

Wild,A. (1958) The phosphate content of Australian soils. *Aust. J. Agric. Res.* 9, 193-204

Finally, this handbook is just one of many resources available. It should be used in conjunction with other resources available, such as field officers, researchers and neighbours who are managing grassy woodland. The forms in Appendix D can be used, copied or adapted as required. For readers without access to high speed internet connections, phone numbers or addresses are supplied for organisations who may be able to provide further information or assistance.

Acknowledgments

We are particularly grateful for comments on the draft by Paul Ryan, Chris Nadolny, Joern Fischer and the anonymous reviewers from Environmental Stewardship.

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Kimberlie Rawlings
David Freudenberger
Dave Carr

Yellow box (*Eucalyptus melliodora*). Illustration: M. Bedingfield

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Part I: Our current understanding of box gum grassy woodlands

By understanding how grassy woodlands function and the processes that threaten them, better management decisions can be made. Ecological understanding allows consequences of management to be more confidently predicted. The information that follows is based on the collective experience of managers and practitioners over the years, and on published research.

Chapter 1. Introduction

1.1 The status and future of box gum grassy woodlands

Status

Box gum grassy woodlands are an iconic part of the eastern Australian landscape. Widely spaced trees, predominantly of the genus *Eucalyptus*, gently shade a native grass and wildflower ground cover. These woodlands are dominated by white box (*Eucalyptus albens*), yellow box (*E. melliodora*), Blakely's red gum (*E. blakelyi*) and (in the Nandewar Bioregion) coastal grey box or inland grey box (*E. moluccana* or *E. macrocarpa*). Box gum grassy woodlands typically exist on the most productive soils throughout eastern and south-eastern Australia, and this is why they have been preferentially cleared for agriculture [1-4]. As a result of this clearing, in combination with high levels of grazing, fertiliser application and cultivation, box gum grassy woodlands are critically endangered [4,5].

Box gum grassy woodlands have been nationally listed as an endangered ecological community [6]. This ecological community supports more than 400 plant species, and animals such as squirrel gliders, goannas, regent honeyeaters, bush stone-curlews and many more. The range of these woodlands once extended across much of south-eastern Australia, from the Murray Darling Depression and Victorian Midlands in a crescent up to the Brigalow Belt South (Figure 1.1). Now, less than five per cent of the original extent of box gum grassy woodlands remains in good condition [7,8]. What remains exists in small, isolated patches across a highly fragmented landscape [9].

Partial or total clearing of the overstorey trees and grassy ground cover for agriculture has resulted in the loss of wildlife habitat and has led to problems like dryland salinity and soil erosion. But it is the on-going uses of the land *after* clearing that have had the greatest impact on box gum grassy woodlands. The effects of grazing by livestock, kangaroos, rabbits and other feral animals; weeds; nutrient inputs from fertiliser, dung and urine; changed fire patterns; lack of tree regeneration; firewood collection; salinity; and soil erosion all threaten the health and persistence of box gum grassy woodlands.

Our woodlands' future

Large-scale clearing of box gum grassy woodlands has largely ceased, but the extent and condition of these woodlands continue to decline. If current degrading

processes are allowed to continue, we can expect box gum grassy woodlands to disappear in many areas. Because most box gum grassy woodland occurs on private land, the efforts of land managers are essential.

Although complete restoration of box gum grassy woodlands across their original range is not realistic, we can conserve, manage and improve what remains, including restoring and rehabilitating those woodlands that are in poorest condition. By targeting the threats to box gum grassy woodlands, and by maximising species diversity and connectivity, these woodlands are more likely to persist over the long term.

Figure 1.1: The geographical distribution of box gum grassy woodlands (BGGW).
NRM = Natural Resource Management.

1.2 Fifteen principles for box gum grassy woodland management

There are a number of underpinning principles, or rules of thumb, for the management of box gum grassy woodlands.

Presented here are the 15 basic principles drawn from what we currently understand about grassy woodlands. They are listed here in order, based on the 'Plan – Trial – Review – Do – Monitor – Evaluate' cycle introduced in Chapter 6.

THE 15 BASIC PRINCIPLES FOR BOX GUM GRASSY WOODLAND MANAGEMENT

1. **Know your objectives, and keep them simple**
2. **Manage for patchiness**
   a. Manage for diversity
   b. Use a diversity of management
3. **Observe before you act, take notes and adapt what you do – forever**
4. **Use the precautionary principle** but don't let lack of knowledge paralyse you (consider Principle 5)
5. **When trying new approaches, test a small patch first** (this is the 'hair colour and carpet cleaner' principle)
   a. This principle does not apply to whole of patch activities such as retaining standing timber and bush rocks, no fertiliser and no cultivation
6. **Restore the basics before attempting to restore the details**
   a. For example, establish native perennials that can reduce nitrate levels before adding or working with forbs or rare species. But see principle 8.c. below
7. **Get the soil nutrient levels right**
   a. Keep soil carbon levels high – perennials are better
   b. Keep soil nitrogen and phosphorus levels low – mine it or lock it up in natives
8. **Maintain ground cover**
   a. Don't create opportunities for weed invasion
   b. Replace what you remove – when taking weeds out develop a strategy for getting natives back, but
   c. Some bare ground is needed to allow for native forbs to establish
9. **Prevent grazing of seedlings and grazing sensitive species**
10. **Minimise edge effects –** for example, create a buffer or lower inputs in adjacent paddocks
11. **Keep the nutrient and water cycles across your whole property in mind**
12. **Use only locally indigenous or locally adapted species for plantings**
13. **Use herbicide sparingly** (see Principles 2 and 8 above)
14. **Seek advice, read widely and discuss your ideas with other grassy woodland managers**
15. **'Quick fixes' often fail – quickly**

Chapter 2. Patterns in box gum grassy woodland remnants

Healthy box gum grassy woodlands typically have widely spaced trees (30–40/ha; Figure 2.1) with a grassy ground cover that includes a stunning diversity of wildflowers [10-12] (Figure 2.2). The number of trees will likely be lower where annual rainfall is below 500 mm and higher where rainfall is above 500 mm. Tree crowns in woodlands typically shade 20–75 per cent of the ground at midday, and trees may reach 30 m tall.

There should be a distribution of ages and sizes of trees in healthy box gum grassy woodlands. For instance, if natural regeneration events occurred every thirty years, at least three age classes would be present (Figure 2.3). Younger trees secure habitat, seed and other resources into the future, and are needed to replace the older trees as they die [10,12,13].

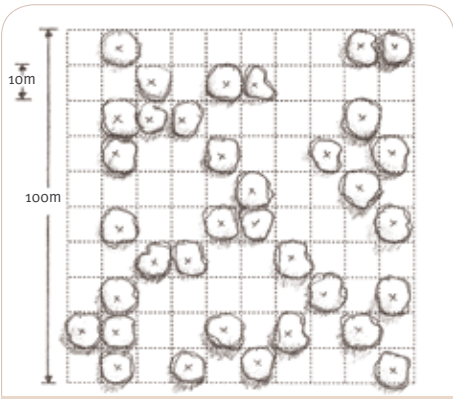


Figure 2.1: A bird's eye view of box gum woodlands, showing a density of 35 trees per hectare.

Species diversity (the number of different plant species) is very high in box gum grassy woodlands, with between 60 and 110 plant species in a high quality patch [8,14]. There are over 400 plant species found across the box gum grassy woodlands range [15]. The ground cover species, including forbs (wildflowers), grasses and sedges, make up most of this diversity [14]. The ground cover, not the trees, is most immediately threatened by clearing, grazing, fertiliser and weeds, and therefore the primary focus for conservation in box gum grassy woodlands.

Figure 2.2: One example of the diversity of wildflowers in box gum grassy woodlands.

This focus on the ground layer means that simply having trees isn't enough. In areas where the trees have been cleared, conservation values are still high if a diverse native ground cover still exists. Such partially cleared areas are called 'derived native grasslands'. The native ground layer provides valuable habitat despite the absence of trees.

2.1 Patterns in vegetation layers

High quality box gum grassy woodlands have several layers of vegetation. The ground itself is covered by leaf litter, lichens and mosses, rocks and logs. Higher up are the grasses and forbs, followed by a few small shrubs and tree seedlings. Large shrubs and trees of different age classes and shapes comprise the mid-storey layer, and mature canopy trees make up the overstorey (Figure 2.3a, 2.3b). Wildlife depends upon this structural diversity because more layers mean more places for animals to shelter, feed and nest [16-18].

Viewed from above, box gum grassy woodland is a patchwork of scattered clumps of trees interspersed with grasses and the occasional shrub. Closer in, there is a 'messy' ground layer of grasses, bare ground, leaf litter, fallen timber and forbs [14] (Figure 2.3c, 2.3d). The bare or litter-covered ground between the tussock grasses is very important: it creates space for forbs,

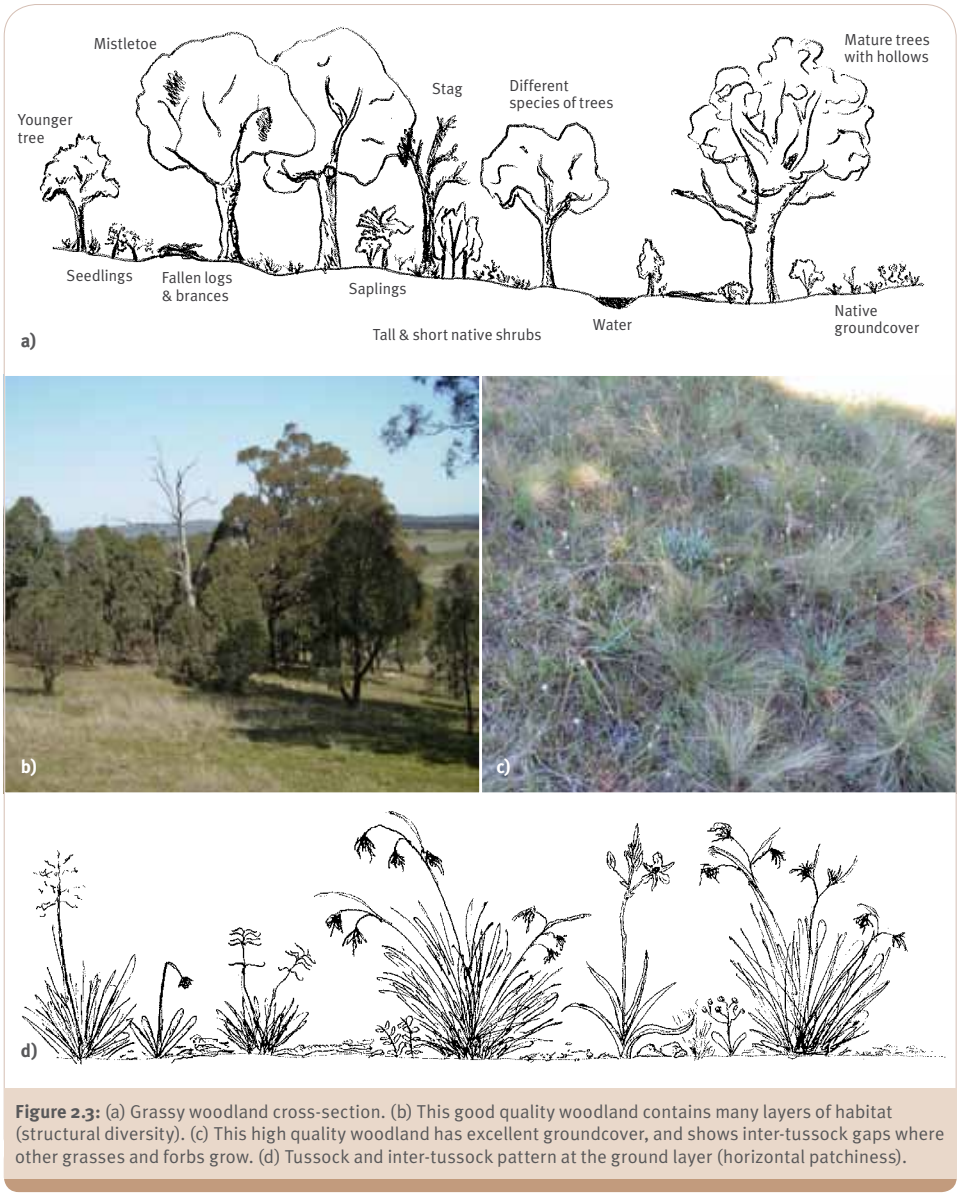


Figure 2.3: (a) Grassy woodland cross-section. (b) This good quality woodland contains many layers of habitat (structural diversity). (c) This high quality woodland has excellent groundcover, and shows inter-tussock gaps where other grasses and forbs grow. (d) Tussock and inter-tussock pattern at the ground layer (horizontal patchiness).

less dominant grasses, lichens and mosses (Box 2.1). Vertical and horizontal patchiness supports a lot of plant and animal diversity.

2.2 What's growing: plant communities and species

Vegetation layers contribute one kind of diversity to box gum grassy woodlands. The presence of many plant *types* also contributes to woodland diversity. Trees and grasses are the most common, but there should also be sedges, rushes, lilies, orchids, climbers, daisies and legumes (forbs like peas and glycines, and woody species like wattles).

But what grows where? The selective nature of clearing, land use and conservation makes determining which species grow where in the box gum grassy woodlands range extremely difficult. However, some patterns do emerge [15].

The dominant canopy trees, yellow box, white box and Blakely's red gum can all co-occur, though white box tends to occur higher in the landscape. Coastal and inland grey box are found as dominants primarily in the Nandewar bioregion (Figure 1.1).

Before European settlement, kangaroo grass (*Themeda australis*) and snow grass (*Poa sieberiana*) were usually the dominant tussock grasses. Queensland bluegrass (*Dichanthium sericeum*) can dominate where the soil parent material is basalt, such as the area north of Tamworth and on the Inverell Plateau. Today, red grass (*Bothriochloa sp.*) and purple wiregrass (*Aristida ramosa*) often dominate in many heavily grazed areas with lower fertility soils in northern New South Wales (NSW).

What grows where is related to climate [15]. Box gum grassy woodlands can be roughly divided into summer-dominant versus winter-dominant rainfall patterns (see glossary; 'northern' and 'southern' regions). Travelling south to north, there is a gradual change in the understory of forbs and grasses. Also, the number of species found only in the north is greater than the number found only in the south.

Weed diversity and abundance also varies with climate. Short-lived weeds tend to be a bigger problem in the south, whereas northern grassy woodlands are more susceptible to invasion by summer-active perennial weeds such as Coolatai grass (*Hyparrhenia hirta*) and African lovegrass (*Eragrostis curvula*).

Snow tussock. Photo: M. Bedingfield

Kangaroo grass. Illustration: M. Bedingfield

BUTTON WRINKLEWORT – A REAL SPACE CASE (BOX 2.1)

Button wrinklewort is a multi-stemmed perennial wildflower (forb) that grows to about 35 cm. It has narrow, dark green leaves and bright yellow, domed 'button' flowers. Button wrinklewort is endangered. It is found only in south-eastern Australia and only in box gum grassy woodlands, derived native grassland or natural temperate grassland – most frequently in the areas where woodland gives way to grassland.

Photo: B. Strong

Button wrinklewort typically grows on soils that are shallow and stony, and in places where competition from other herbaceous plants is low. It is also able to colonise bare, recently-disturbed ground; though it is not a good competitor against the weeds that thrive in these spots.

Button wrinklewort's niche is the space between tussocks of long-lived native grasses. It is sensitive to grazing – tolerating only light grazing by sheep after the peak flowering season (summer). Infrequent fire also threatens this plant. Many of the remaining populations are small and suffer from loss of genetic diversity.

Conservation of button wrinklewort will depend on maintaining open inter-tussock spaces, restricting or eliminating grazing, preventing further habitat loss, and improving genetic diversity in small populations.

Broom bitter-pea (*Daviesia genistifolia*).
Illustration: M. Bedingfield

Chapter 3. Processes in box gum grassy woodlands

3.1 Ecosystem function: how a healthy woodland works

Healthy box gum grassy woodlands provide a wide range of benefits that are often called 'ecosystem services'. These include traditional services like grazing for livestock, but also other services such as:

- **capture of solar energy**
- **soil formation and cycling**
- **nutrient cycling**
- **water capture, filtration and delivery to water bodies**
- **pollination**
- **pest management**
- regional climate buffering
- shade and shelter
- breakdown and absorption of wastes
- a sense of place
- pleasing views.

All of the these services are important but those in bold are directly relevant to woodland management activities.

Capture of solar energy

Ultimately, all energy comes from the sun, but plants use and store less than one per cent of the solar radiation reaching Earth. Solar energy, in the form of carbon, flows from plants to herbivores to carnivores and finally to decomposers [19]. As these decomposers die, the end product is carbon dioxide. The capture of solar energy by woodlands is the foundation for virtually all other processes.

Soil formation and cycling

Particles of rock, water, decomposing plant material and soil organisms are the building blocks of soil. A woodland is supported by soil that has been created over many millions of years. Woodlands don't need fertiliser. Plant nutrients like phosphorus are continuously being recycled by decomposers like insects and fungi that break down leaf litter and dead roots into humus. This organic matter slowly releases plant nutrients that are taken up by the roots of living plants. Nitrogen in the air is taken up by free-living bacteria in the soil, or bacteria closely associated with the roots of legumes like acacias, she-oaks (*Casuarina* species) and native peas (*Glycine* species). In a healthy woodland, little soil is lost to wind or water erosion due to the sheltering effects of groundcover.

Nutrient cycling

Nutrient cycling is the term used to describe the movement and supply of different nutrients that plants (and animals) use in a given ecosystem. In box gum grassy woodlands, the supply and movement of nutrients such as phosphorus (P), nitrogen (N) and carbon (C) are determined by the death and breakdown of plant material by decomposers, by moving water, by plant species composition, and to some extent by fire [19,20]. Nutrients from plant material are recycled through the decomposition of litter and incorporated into the soil to be used again by plants [21].

Too many soil nutrients are a far greater problem in maintaining a healthy woodland than too few. The cycling and management of soil and plant nutrients is covered in detail in Chapter 11.

THE WEB OF LIFE

Plants are the foundation for the web of life. Trees, grasses and forbs provide food for insects that are often consumed by the spectacular diversity of woodland birds. These same plants die and form litter that protects ancient soils from erosion. This litter is broken down by fungi, termites and beetles whose digging increases the ability of water to filter into the soil and promote further plant growth. This complex and diverse web can collapse as the result of over grazing, tree dieback and failure of tree regeneration.

Water capture, filtration and delivery to water bodies

In little-disturbed box gum grassy woodlands, virtually all of the water that comes in as rainfall is harvested and used by the vegetation [22]. This water either evaporates, is incorporated into plant material, or is transpired by the vegetation. Any uncaptured water leaves the system as runoff or drains to groundwater.

This water balance can be easily disturbed. Clearing directly reduces the amount of water that can be harvested by vegetation, increasing runoff and erosion risk. Clearing at large scales has been found to increase surface temperatures and decrease summer rainfall in south-east Australia [23]. Grazing and other forms of soil disturbance can affect infiltration rates through compaction as well as changes in soil structure, nutrients and the abundance of soil organisms. More information on altered hydrology can be found in Chapter 4.

Pollination and pest management

Healthy woodland patches are full of pollinators: birds, bats and many species of insects. These animals pollinate native plant species, but also provide the critical service of pollinating crops.

Bats, birds and native invertebrates are excellent consumers of insect pests [24]. Bats can consume up to half their body weight in insects per night, making a substantial contribution to pest control in both woodlands and surrounding agricultural land.[25]. Many box gum grassy woodlands have between ten and fifteen bat species or species groups [26,27], and often many dozens of individuals for a given site. Most of the insect-eating bats are very small, and roost in small cracks or hollows in both live and dead trees [27-29]. Woodland remnants and scattered paddock trees support bat species and the bats in turn contribute to tree, woodland, and agricultural health.

The importance of individual woodland components

Some individual components have a clear and positive effect on woodland functioning. A few of these are described here.

Trees

Trees are the most visible feature of box gum grassy woodlands and contribute substantially to ecosystem function. Some of the most obvious contributions of trees are to provide shelter, food and breeding habitat for birds, native mammals, reptiles, frogs and insects. This is true for trees in woodlands as well as scattered or isolated trees in paddocks (Box 3.1)[30].

The soils under woodland trees have naturally higher nutrient levels and plant species diversity [31-33]. Trees are associated with enhanced water infiltration and improved soil health [34,35]. Deep roots and high water use help prevent rising water tables [34,36]. Smaller trees improve structural diversity (described in Chapter 2), provide shelter for birds and represent the 'next generation' of trees.

Logs and litter

Logs and litter on the floor of grassy woodlands perform many important functions. Litter is the dead plant material that accumulates on the ground. It can come from grasses, forbs and trees.

Logs and litter are an important part of nutrient cycling and plant establishment. They protect soil from rain drop impact and water erosion, while at the same time allowing for water infiltration. The many nooks and crannies of fallen logs and branches provide safe, nutrient-rich sites for seeds to germinate, and anchor points for lichens and mosses. Large fallen trees, parts of trees and dead standing trees take a long time to break down. During the process of decomposition, dead plant material feeds soil microbes and fungi, which in turn provide the nutrients to feed the plants themselves.

Logs and litter also provide critical habitat for many woodland species, including more than twenty species of birds (Box 4.2). Many invertebrates are dependent on fallen timber for their survival. Fallen timber of various sizes, stages of decay, and position in sun or shade, are important because they all host different species of invertebrates and fungi [42].

Thus, the 'keep it messy, mate' principle is about preserving the functions that fallen branches, decaying logs and leaf litter provide. Some people see fallen branches

OUTSIDE THE PATCH (BOX 3.1)

'Scattered trees are keystone structures'

The keystone of an arch is roughly the same size and mass as the other stones, and yet it holds the whole arch together. Similarly, scattered trees in paddocks have a disproportional effect on ecological processes relative to their mass and the space they take up [37]. The loss of a single paddock tree has a greater ecological effect than the loss of a single tree within a woodland remnant. There are several reasons for this.

- Scattered trees act as stepping stones. They are points of refuge, rest and food for mobile species in an otherwise inhospitable landscape. Birds, bats and beneficial insects are more abundant and diverse when scattered trees are in a paddock. Over the landscape, scattered trees add to connectivity for both animals and genetic information.
- Soil nutrients, water infiltration, plant and insect diversity, and shade and shelter are higher under and near scattered trees compared with a treeless paddock [37,38]. In many of the productive landscapes of SE Australia, scattered trees make a significant contribution to total tree cover [39].
- Paddock trees can provide a potential 'hub' for revegetation or natural regeneration. They are windows to the past, because most pre-date original clearing by European settlers.

Over the vast majority of south-eastern Australia, scattered trees are not regenerating [40,41]. This 'tree regeneration crisis' [41] has serious implications for wildlife, production, and nutrient and water cycling [37].

Photo: K. Sherren

and logs as havens for rabbits and hares. Pest animals do use these features, but so do our native wildlife. There are other ways to control rabbits besides burning or removing fallen timber.

Groundcover

The different native grasses and forbs each have a role to play in the woodland or grassland. Native grasses supply seed for a diversity of native birds and small mammals. Perennial tussock grasses provide shelter to small animals like lizards. Different grasses respond to different rainfall events. Some grasses grow rapidly on cool season rains, others thrive on summer rains. Woodlands can still function well without every species being present, as more than one species can perform the same job. But if too many species are lost, some important functions will disappear and the health of the woodland starts to suffer.

Limiting factors in grassy woodlands

In many ecosystems, there are some things that are scarce in extent or amount. These 'limiters' are what can make an ecosystem unique and function in a stable manner. If the limiting factor, or constraint, is removed, things change. One example of this concept includes the low inherent nitrogen and phosphorus levels in grassy woodlands, which limit plant growth and species composition. By adding nutrients, we remove the constraint, and things change — weeds and other exotic species start to take over.

Water is another major limiting factor in Australian ecosystems. Before European settlement, animals such as grey kangaroos had to move between water sources, since watercourses naturally dry up soon after rainfall. These movements created a grazing pattern similar to crash grazing followed by long periods of rest. Kangaroo populations were partially kept in check by shortages in permanent water, but with the construction of hundreds of thousands of dams, this limiting factor has essentially been removed. Kangaroos have proliferated, and overgrazing by them can cause almost as much damage to plant communities as overgrazing by livestock.

In combination with limited water, Aboriginal people and dingoes kept herbivore numbers in check. These limiting factors are now virtually absent in Australian farming landscapes. The reality is that we have fundamentally changed the ecological relationships between predators and prey that existed before European settlement. If we wish to restore ecological function, then these relationships should be taken into consideration. Reinstating these limiting factors is an ongoing challenge for grassy woodland restoration.

3.2 State and Transition Models

Fire, grazing, clearing, weed invasion and fertiliser are environmental processes that greatly influence the character, health or 'state' of box gum grassy woodlands. Box gum grassy woodlands are a mosaic of smaller ecosystems in different conditions [43]. This section explores one way to think about the condition of a woodland, how it got to be that way, and what changes are possible under *status quo* or changed management. This way of looking at woodland conditions and pathways of change is called a 'State and Transition Model.'

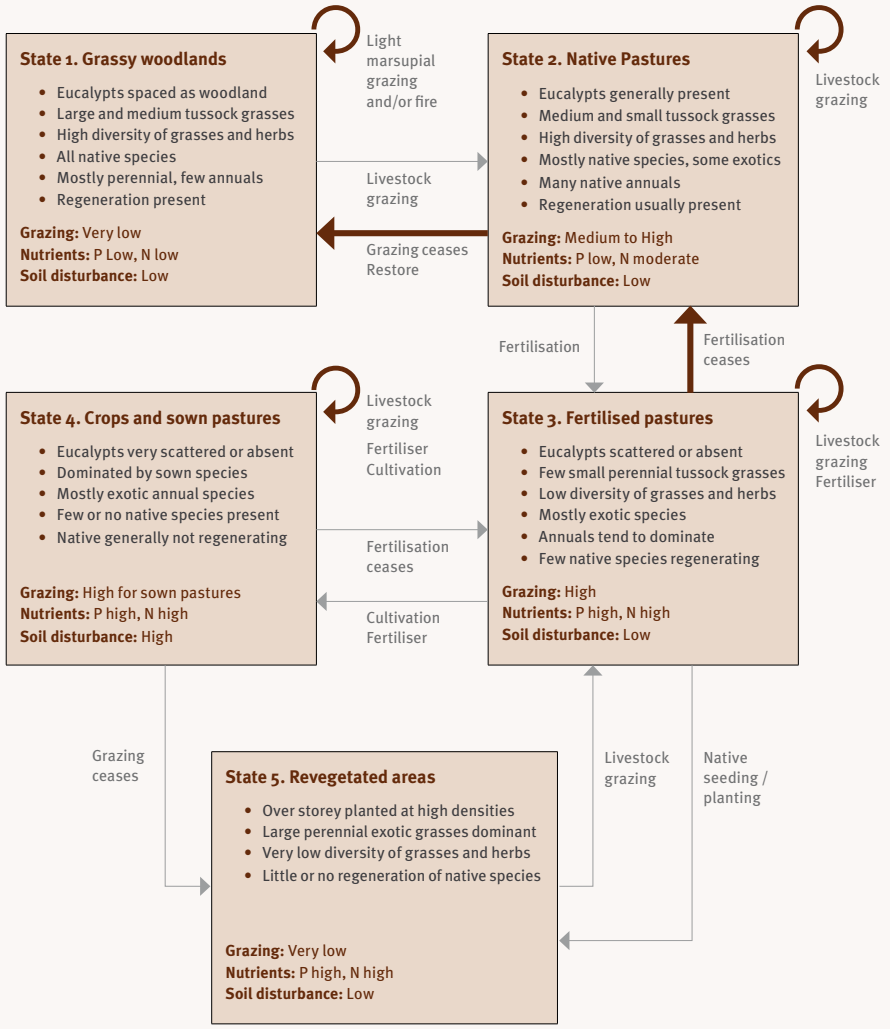


Figure 3.1: The box gum grassy woodland State and Transition Model. The model has five states, each listing the characteristics typical for that state. Arrows between boxes represent the transition or change between states and the management activities that cause the transition. Thick arrows represent a more difficult transition. Circular arrows describe the mechanisms for maintaining a given state.

What is a State and Transition Model?

A State and Transition Model is a way of looking at an ecosystem in order to make sense of changes in vegetation composition and structure. State and Transition Models are based on the assumption that an ecosystem exists in a relatively stable *state* until a disturbance (such as fire, flood, grazing) is significant enough to cause a *transition* to another relatively stable state [44]. For example, persistent grazing and the introduction of weeds can cause the transition from a native perennial understory to a weedy and short lived understory (Figure 3.1).

The State and Transition framework recognises that some transitions (vegetation changes) can cross a *threshold*, such that simply removing the process that caused the transition will not change the ecosystem back to the previous state. Like the term suggests, thresholds are boundaries. For example, many grassy woodlands will not move to a more desirable state just by removing livestock. Grazing has caused the depletion or local extinction of some native plants because there are no seeds left in the soil. Management will require planting these species in order to move (transition) the woodland towards the more desirable state. Sometimes, restoration to a former state will be impractical. For example, restoring a woodland that includes an abundance of digging bettongs and potoroos is only possible in small areas that can be kept fox and cat free.

Why are State and Transition Models useful?

A State and Transition Model describes the characteristics of different states and identifies the drivers of change. It can identify where thresholds may exist and the ecological consequences of crossing them.

Using a State and Transition Model can help to determine what factors may have led to an undesirable state, and where one might focus efforts in order to improve woodland condition.

The State and Transition Model for box gum grassy woodlands is a simplified representation of the real world, so for example, simply ceasing fertiliser application will not necessarily turn a State 3 woodland into a State 2 [45] (Figure 3.1). In reality, most improvements to woodland condition will be gradual and incremental [46]. The changes that do occur are often the result of a combination of factors. Moving a woodland from one state to another is likely to take high levels of management over a long period of time, sometimes at high cost.

3.3 Assessing the state of a woodland remnant

It will take some time to become familiar with what state your woodland is in. It may all be in the same state or be made up of smaller areas in different states. The diagram above, the state descriptions below and the next chapter will help familiarise you with the state of your woodland. It is also useful to spend some time simply observing what's happening in your box gum grassy woodland. Consider the woodland's history of both human-controlled and natural events.

Appendix D1 contains a woodland features and condition score sheet. This form can be used to do a self-assessment of a patch or a specific part of a patch. It can also be used to monitor condition and progress at the patch scale. For more information on monitoring, see Chapter 7. For a list of the species commonly associated with each of the following states, see Appendix A1 and Table 3.1.

State 1: Grassy woodland

In State 1 grassy woodlands, the cover of mature trees is well spaced, with younger trees of different ages and sizes (Figure 3.2). A State 1 patch has high native species diversity, including grasses as well as forbs, and many different life forms. A variety of shrubs are also present, though sparsely distributed. Mistletoes are likely to be present, but at low rates. The only current impacts to perennial native vegetation are light grazing and possibly fire. There has been no history of cultivation, no past fertiliser use, and only occasional livestock grazing if any.

Derived native grasslands (i.e. grasslands derived from the clearing of overstorey trees) can also be in State 1, provided the groundcover vegetation is native and highly diverse. State 1 derived native grasslands are likely to be rare, since some form of stock grazing usually followed clearing of the canopy. The best examples of State 1 derived grasslands are in cemeteries and road and rail reserves.

State 1 woodland is vulnerable to the same external pressures and edge effects as woodland in any other state. Larger woodlands will be more resilient to the pressures of nutrient run-on, inappropriate fire regimes and weed invasion than smaller patches in State 1. To maintain woodland in State 1, the main management activities are likely to be monitoring for and managing weeds and changes in soil nutrient levels (especially at the edges), and managing total grazing pressure.

State 2: Native pastures and woodland

When a State 1 grassy woodland is subjected to intense and prolonged grazing it will probably transition to State 2. Canopy trees are still present, widely spaced, and of different ages (Figure 3.3). However, the mid-storey species will have changed due to the effects of grazing. Native grass species diversity can still be high in State 2 woodland or derived grassland, but grazing sensitive species such as kangaroo grass will be rare or no longer present, being largely replaced by spear-grasses (*Austrostipa* spp.) and wallaby grasses (*Austrodanthonia* spp.). State 2 woodland groundcover comprises predominantly native grasses and forbs, but there are likely to be fewer plant types than in a State 1 site and some non-native species will be present. Some shrubs may be present, particularly the colonising *Cassinia* species, though wattles are rare.

Figure 3.2: State 1 woodland. Photo: R. Rehwinkel

Figure 3.3: State 2 woodland. Photo: P. Spark

Figure 3.4: State 3 derived native grassland, with a history of fertiliser use and grazing. Native plant species are still present, but groundcover species are predominantly exotic.

Many derived native grasslands are in State 2 because they were originally cleared for agricultural purposes. Therefore some stock grazing and fertiliser application is likely to have occurred.

Unlike in State 1 sites, groundcover in State 2 will be more uniform in height, have more weedy annuals and have a lower diversity of perennial native forbs that are palatable. Grazing and altered nutrient status are key drivers of the change from State 1 to State 2, so reversing these changes through weed and grazing control are key management activities in State 2 woodland. Over time, and with the right seasonal conditions, the patch may show progress towards State 1. Some native species, such as those quickly lost from State 1, may need to be added (Table 3.1).

State 3: Fertilised pastures

Fertilisation, often in combination with grazing, is likely to cause a State 2 woodland to transition to State 3. Increased nutrient levels in the soil (particularly phosphorus and nitrates) facilitate the widespread establishment of weeds. State 3 woodlands usually consist of an understorey of mostly exotic grasses and just a few natives (Figure 3.4). Dominant canopy trees are still present in woodlands, but few are regenerating and some may show signs of dieback. Plant species diversity overall is likely to be low. The effects of grazing and fertiliser can make rehabilitation of State 3 patches difficult, and a suite of management activities will probably be required. A key objective will be to diminish competition from exotics and encourage the native species that may still be present in the soil seed bank.

Figure 3.5: State 4 crops and sown pastures. Photo: P. Ryan

Figure 3.6: State 5 revegetation site. Photo: D. Carr

State 4: Crops and sown pastures

State 4 areas are dominated by exotic species which were deliberately sown. There are few or no native shrubs or mid-storey species, although there may be some remnant native seeds in the soil. Canopy species may still be present, but they are likely to be scattered and not regenerating (Figure 3.5).

There are likely to be high nutrient loads and high soil disturbance in State 4. Livestock grazing, fertiliser and cultivation will maintain a patch in State 4. Over the long term, ceasing these activities will begin to move a State 4 patch towards a State 3 patch, but weeds and introduced pasture species will continue to dominate. Regeneration of native perennial tussock grasses will depend on soil seed stores or windborne seeds. Restoration and revegetation of State 4 will often require 'starting from scratch', using high-disturbance planting methods described in Chapter 15.

State 5: Revegetated areas

State 5 patches are characterised by a weedy groundcover and often dense cover of planted trees and shrubs. State 5 patches have a history of cropping and fertiliser, so weeds and high nutrient levels are likely to persist for some years. State 5 patches can provide habitat for many small birds [47].

Species diversity in State 5 patches is often low. Rehabilitation to a better state will require active management, including thinning of planted overstorey and mid-storey and control of weeds through strategic grazing and selective herbicide application. Planting of native groundcover species may also be necessary to move a State 5 patch towards a more desirable state.

Table 3.1
Plant types and some indicator species for States 1, 2 and 3. The species listed are only examples.

Vegetation layer	State 1	State 2 (soil type and grazing history dependent)	State 3 (soil type and grazing history dependent)
Canopy	The canopy species will have a range of ages, from mature trees with hollows to seedlings.	Except in derived grasslands, the dominant canopy species are present, with a good representation of tree ages.	Canopy species are still present in woodlands though there are few young trees and seedlings.
Shrubs	Many of the leguminous (pod-bearing) shrubs are found only in State 1. Due to their high nutritional value, young plants are quickly grazed out in other states. Examples include: • Wattles (*Acacia* spp.) • Indigos (*Indigofera* spp.) • Common fringe-myrtle (*Calytrix tetragona*) • Bush-peas (e.g. *Pultenaea* spp., *Daviesia* spp., *Dillwynia* spp.) • Cryptandras (*Cryptandra* spp.)	While many shrubs are still present in State 2, they are likely to be mostly the colonising species like Cassinias. Grazing-sensitive shrubs such as most of the wattles, the indigos and cryptandras are probably no longer present unless protected. Examples include: • Some heaths, such as urn heath (*Melichrus urceolatus*) and peach heath (*Lissanthe strigosa*) persist where protected • Grey Guinea-flower (*Hibbertia obtusifolia*)	Most shrubs in State 3 will be exotic. Native shrubs that persist in State 3 are those that are highly unpalatable due to thorns or other features. Examples include: • Blackthorn (*Bursaria spinosa*) • Cassinias, Chinese shrub, sifton bush, etc (*Cassinia* spp.)
Groundcover – forbs (wildflowers)	Plants with tall, flowering stems which are sensitive to grazing may only be found in State 1 including many lilies, orchids and daisies. Examples include: • Native flax (*Linum marginale*) • Donkey orchids (*Diuris* spp.) and sun orchids (*Thelymitra* spp.) • Yam daisy/murrnong (*Microseris lanceolata*)	Forbs are transitional in form, between the tall, fleshy plants found in State 1 and those of shorter stature that are often found in State 3. State 2 forbs will often have persistent root stock, tough, rough or hairy leaves, which makes them more resistant to grazing. Examples include: • Sedges (*Carex* spp.) • Mat-rushes (*Lomandra* spp.) • Early Nancy (*Wurmbea* dioica) • Chocolate lilies (*Dichopogon* spp.) • Common buttons (*Chrysocephalum apiculatum*) • Native plantains (*Plantago* spp.) • Common raspwort (*Gonocarpus tetragynus*)	In general, the groundcover in State 3 will have traits adapted to elevated nutrients, competition and grazing. These plants will be annuals (a), short-lived perennials (sp), short-flowering (sf), rosette forming (r) or stoloniferous (st). Examples include: • Bluebells (*Wahlenbergia* spp.) (sp) • New Holland daisies (*Vittadinia* spp.) (sp) • Austral sunray (*Triptilodiscus pygmaeus*)(a) • Blue heron's-bill (*Erodium crinitum*) (a) • Austral bear's-ear (*Cymbonotus lawsonianus*)(r) • Solenogynes (*Solenogyne* spp.)(r) • Kidneyweed (*Dichondra repens*) (st)

Vegetation layer	State 1	State 2 (soil type and grazing history dependent)	State 3 (soil type and grazing history dependent)
Groundcover — grasses	Grasses that are typically sensitive to grazing will only persist in State 1. These include: • Kangaroo grass • Barbed-wire grass (*Cymbopogon refractus*) • Wild sorghum (*Sorghum leiocladum*)	Many of the warm-season and highly grazing sensitive grasses found in State 1 are no longer present in State 2. Common State 2 grasses include: • Nine-awn grass (*Enneapogon nigricans*) • Plume-grasses (*Dichelachne* spp.) • Common wheat-grass (*Elymus scaber*)	There are many native grasses that become more common with grazing. In State 3, these species will move towards co-dominance with the exotics that are present. Some examples: • Weeping grass (*Microlaena stipoides*) • Red grass (*Bothriochloa macra* or *B. decipiens*) • Wallaby grasses (*Austrodanthonia* spp.) • Purple wire-grass (*Aristida ramosa*)
Exotic species	Occasional woody weeds from seeds carried in bird droppings.	Shrubs: • Blackberry (*Rubus fruticosus*) • Briar rose (*Rosa rubiginosa*) • African box-thorn (*Lycium ferocissimum*) Groundcover: • Paterson's curse (*Echium plantagineum*) • Capeweed (*Arctotheca calendula*) • Fescues (*Vulpia* spp.) • Bromes (*Bromus* spp.) • Coolatai grass (*Hyparrhenia hirta*) • African love-grass (*Eragrostis curvula*) • Thistles (various species)	Exotic species commonly found in State 3 are similar to those in State 2 but more abundant.

Chapter 4. Disturbance in woodland patches: how and why things change

Disturbance occurs naturally in box gum grassy woodlands. Marsupial grazing, fire and drought have shaped the features of grassy woodlands over millennia. The frequency and intensity of these disturbances particularly affect plants, the amount of litter and bare ground, and soil moisture. Some types of disturbance, for example fire and grazing, reduce the dominance of perennial grasses and create bare ground for forbs and less dominant grasses to establish. So, these types of disturbance can be a positive force in woodlands.

Disturbance levels can change the characteristics of grassy woodlands. For example, low disturbance leads to large tall plants, abundant litter and little bare ground. High disturbance typically leads to smaller, shorter plants, with less litter and more bare ground. Cultivation, clearing, forestry, changed fire regimes, herbicides and introduced pastures have all affected grassy woodlands, but fertiliser application and grazing of domestic livestock have had the most significant impact. Today, there is virtually no woodland that has escaped all of these disturbances.

4.1 Disturbances that threaten box gum grassy woodlands

Disturbance is not limited to what happens inside the patch, nor is it limited to a particular point in time. Edge effects (see glossary), current adjacent land use, and the legacy of past land use also exert pressure on remnant woodland at different scales of space and time (Table 4.1).

Clearing and fragmentation

Box gum grassy woodlands have been cleared to a small fraction of their original extent. Aside from the direct loss of habitat for wildlife, clearing fragments the remaining woodlands. Fragmentation is the breaking apart of continuous woodland into many small patches. It typically leads to lower species diversity and lower population sizes, for both animals and plants [48]. Some animals need large areas or particular features, so cannot survive in small fragments. Similarly, if the distance between fragments is too large, then breeding, feeding and dispersing must occur in a single patch, and it may not be big enough. Thus, the presence of a long-lived species in a remnant does not guarantee it can persist there in the long term.

Like animals, not all plants are distributed evenly across the landscape. For some remnants, it is pure luck that some uncommon or rare species happened to be where the vegetation was left standing. Clearing of the most fertile patches of land first means that the plants associated with these soil types and locations have been most affected.

In the southern region of box gum grassy woodlands, remnants are often less than 1 ha and surrounded by more intensive land use [39]. Here, fragmentation effects are particularly evident. In the northern, summer-rainfall region clearing has not been as complete and tree cover is mixed with pastoral land uses. Fragmentation effects are not as strong here, but disturbance is high and the mid-storey and groundcover are often highly altered. Distinct remnants with high-quality groundcover can be difficult to find and are therefore very valuable.

Livestock grazing

Grazing removes or reduces some plant species, stops flowering and seeding in others, increases nutrient concentration and soil compaction, favours weed invasion and can create bare ground with associated higher erosion risk (Box 4.1). It can lead to a decline in native perennial cover, reduced biological soil crust cover (mosses and lichens), reduced leaf litter, reduced water infiltration and a decline in native fauna including insects [49-52].

Table 4.1.
Disturbances that affect box gum grassy woodlands at different time and spatial scales. Over time, some disturbances are new, while some have been lost.

Time →

Scale ↓

	Current and recent past	Intermediate past (20-80 y.a.)	Historical past (80-200 y.a.)	Evolutionary past
Within the remnant	Livestock grazing Nutrient enrichment Soil disturbance Lack of fire Marsupial grazing Firewood collection	Nutrient enrichment Herbicide Grazing Cultivation Thinning Loss of species and function Changed hydrology Weed invasion Firewood collection	Livestock grazing Marsupial grazing Thinning and clearing Loss of species and function Firewood collection	Aboriginal fire Flood Drought Marsupial grazing/ digging Wildfire Pests and disease
Adjacent land	Nutrient enrichment Livestock grazing Weed source Cultivation Thinning and clearing Pesticides Rising water table	Nutrient enrichment Pasture improvement Weed source Cultivation Thinning and clearing Pesticides Changed hydrology	Clearing and fragmentation Loss of species and function Soil disturbance Changed hydrology	Aboriginal fire Flood Drought Wildfire Pests and disease
Landscape scale	Changed hydrology Loss of connectivity Changed fire regimes Drought	Changed hydrology Loss of connectivity Changed fire regimes Drought	Loss of connectivity Drought Flood	Flood Drought Wildfire Pests and disease

Grazing is a threat but it can also be a positive tool for management. Many practitioners and researchers have found that high-intensity, short-duration rotational grazing of domestic livestock, which allows adequate 'rest' time between grazing periods, can improve the groundcover and species mix (especially of grasses) in many pastures and woodlands [53].

Figure 4.1: 'Domestic grazing animals have been described as having a slasher out the front, four little cultivators underneath, and a fertiliser spreader out the back' (T.A. Wright in [53]). Illustration: S. Couper.

MURRNONG: STAMPING OUT A STAPLE FOOD (BOX 4.1)

Murrnong, or yam daisy (*Microseris lanceolata*) was a very important staple food for Aboriginal groups in south-eastern Australia. The tuberous roots of this perennial herb are rich in starch, much like a potato or yam. The roots of other plants such as orchids, bulbine lily and chocolate lily were also commonly eaten. These food plants were common and widespread, because Aboriginal land management included patchy fires to open up the grass canopy, creating a mosaic of sites in different stages of fire recovery.

The digging up of yam daisies disturbed the soil in a very different way to the hooves of sheep, cattle and goats, which are non-targeted and mostly compact rather than loosen soil. The widespread decline of yam daisies has been caused by inappropriate soil disturbance and their high palatability to livestock [54].

Yam daisy flower. Photos: B. Strong

Yam daisies look a lot like introduced dandelion or cat's ears. The main differences are in the leaves — which are slender and erect — and the way the stem of the yam daisy bends over like a shepherd's crook before the bud opens, then straightens out again once open.

In continuous (set) stocking, domestic livestock have the opportunity to graze some species preferentially, while leaving the less palatable species. Under moderate to heavy grazing, warm-season perennials like kangaroo grass and native legumes like glycines are the first to disappear because they are highly palatable and their seeds are short-lived. Under heavy or persistent grazing, the groundcover will transition away from tall tussock and flowering plants towards cool-season perennials and low growing or fibrous grazing-tolerant plants. Weeds will colonise denuded areas.

Nutrient enrichment

The ancient soils under most grassy woodlands are naturally low in fertility [55]. Nutrient enrichment is a threat to healthy and diverse woodland and although we often believe 'more nutrients are better', many native plants and trees are greatly disadvantaged by added fertility from livestock dung and chemical fertilisers. Eucalypts can put added phosphorus and nitrogen into rapidly growing leaves, but

Figure 4.2: Dieback. Photo bottom: C. Totterdal

these nutrient-rich leaves become very attractive to insects like leaf beetles. This kind of insect attack is one of the primary causes of tree decline, or 'dieback' [49,56] (Figure 4.2).

Native groundcover also struggles with nutrient enrichment, particularly if it is accompanied by increased grazing pressure. The highly diverse groundcover of a healthy woodland has not evolved to cope with high nutrient levels. Many agricultural weeds are just the opposite: they thrive in fertilised paddocks and sheep camps. Introduced plants like cape weed, Paterson's curse and annual rye grass thrive in nutrient-enriched soils and rapidly out-compete many native wildflowers, grasses and tree seedlings. These weeds then die and break down rapidly over summer, releasing their nutrients in the autumn for the next generation of weeds to grow. This annual cycle is difficult to break and so this type of system is very resistant to change.

Elevated nutrients can persist in the soil for many decades no matter what the soil type. Land use history leaves a long legacy, which needs to be considered when assessing soil nutrient levels and other disturbances.

Weedy exotic plants

Weedy introduced plants have few natural enemies or limiting factors, especially when soil nutrients are high. Weeds are adapted to colonise and spread.

Both exotic annuals and perennials threaten box gum grassy woodlands through a number of mechanisms discussed in more detail in Chapter 10. Annuals grow when the native perennials are dormant, beginning in the inter-tussock spaces and leaving the native forbs and less dominant grasses with nowhere to grow. If left unchecked, especially in the presence of heavy grazing, annual weeds will also replace many native tussock grasses.

Exotic perennials have the potential to cause local extinction of many groundcover species. Because of this, invasion of native plant communities by exotic perennial grasses has been listed as a Key Threatening Process under the *Threatened Species Conservation Act 1995*.

A dense sward of exotic grasses stresses trees, too[49]. Native perennial tussock grasses are deep rooted and grow in clumps. Their deep roots and the uncompacted, protected soil between them greatly aid the infiltration of water deep into the soil profile, allowing native tussock grasses and trees to coexist [34,57]. In contrast, exotic grasses grow densely and have shallow roots. This prevents water from reaching the root zone of the trees, leading to water stress in the trees. Exotic grasses also reduce habitat for reptiles and ground feeding and nesting birds.

Fire

Fire is not a new disturbance in grassy woodlands, but is in fact an integral part of their functioning [58]. It is the change in fire regimes that threatens grassy woodlands.

Historical fire regimes

Fire can stimulate regeneration by opening the canopy or creating bare patches where new plants can establish. Fire and smoke are also cues for seed release or germination in some native Australian plants. Hot fires would have killed many ground layer plants and some trees, whereas cooler fires adjusted the dynamic between dominant grasses and subordinate grasses and forbs.

Aboriginal use of fire involved patchy fires of varying sizes and in varying seasons. Reasonably regular fire intervals in south-eastern Australia reduced tree, shrub and grass density in grassy woodlands, creating favourable conditions for the tuberous plants that were a major part of the Aboriginal people's diet [54,59 60] (Box 4.1). The resulting mosaic of burnt and unburnt patches contributed to local and landscape heterogeneity, and helped preserve species diversity.

Inappropriate fire regimes

Since European settlement, fire has largely been suppressed in the temperate areas of box gum grassy woodland. Perceived risk of wildfire and general lack of understanding about the benefits of intermittent fire are partly to blame. Without fire, or disturbance that mimics fire, the balance between trees, grasses and forbs is often tipped towards a denser canopy and domination by a few grass species or shrubs [61].

Too much fire, on the other hand, can start a cascade of conditions that ultimately lead to serious land degradation [62] (Figure 4.3). For example, burning every two years for biomass control may lead to changed soil surface conditions such as reduced litter, increased compaction, decreased infiltration and less biological activity. These changes can lead to poor recovery after drought or another fire.

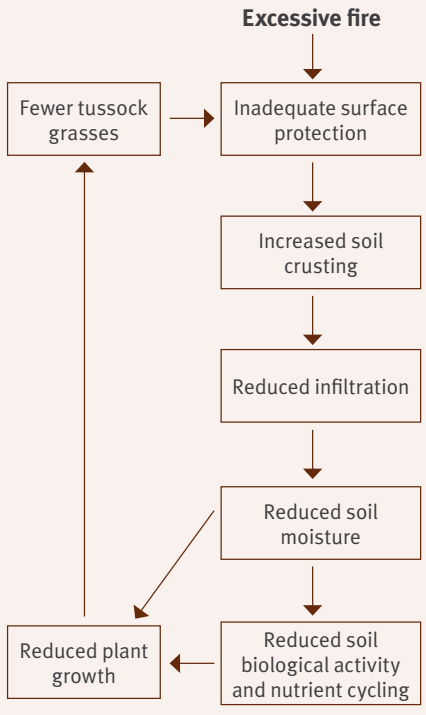


Figure 4.3: Too-frequent fire can begin processes of degradation that lead to an ongoing cycle of poor plant growth. Adapted from Prober (2008).

Changed hydrological regimes

A hydrological regime is the regular pattern of movement of water over space and time. Humans have been changing natural hydrological regimes since the advent of agriculture, by creating dams, contour banks, channels and bores, and clearing vegetation. Two negative consequences of changed hydrological regimes are secondary salinity and erosion.

Secondary salinity

Before extensive clearing, deep rooted native vegetation was able to intercept and transpire virtually all of the water from a rain event, leading to very little run-off or ground water recharge in catchments [22]. Clearing has changed soil structure and reduced water capture, causing higher rates of runoff, increased groundwater recharge and rising water tables [63].

When natural salts are mobilised and brought to the soil surface in rising groundwater, dryland salinity results. In the agricultural landscapes of south-eastern Australia, especially in the wet soils and the fragile, duplex soils typical of this region, surface water salinity also occurs. Here, saline surface water accumulates in areas of soil degradation (for example from intensive grazing) [64].

Salt stresses or kills plants that are not adapted to high salinity. Loss of salt-sensitive vegetation is tantamount to further clearing, causing yet higher water tables. The process continues until vegetation loss is complete or a new suite of salt-adapted species creates a novel ecosystem. Water tables that are high adjacent to remnant woodland slowly kill edge vegetation and decrease the size of the remnant [36] (Figure 4.4).

Erosion

Soil disturbance by clearing, livestock or cultivation poses an erosion risk. Bare soil is at risk of being blown or washed away. Even high-quality woodland with high ground

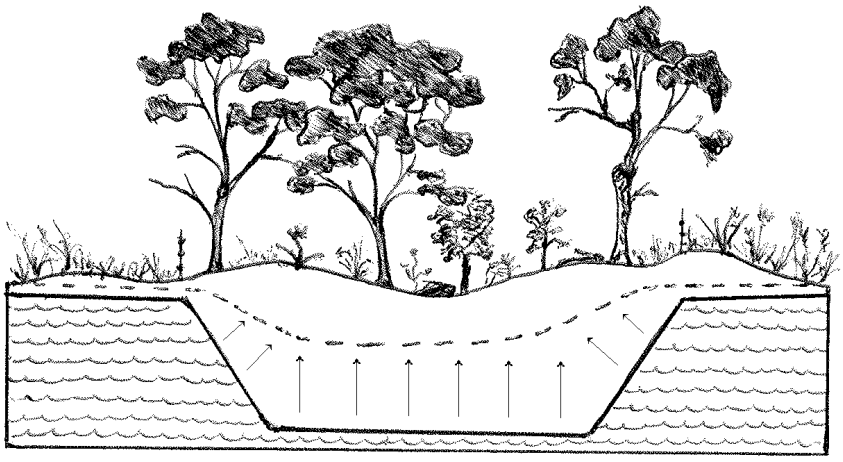


Figure 4.4: The edge effect created by rising saline groundwater. As edge vegetation becomes salt affected and dies off, loss of deep-rooted vegetation allows water tables to rise further, encroaching on the woodland.

layer species richness and good vegetation structure can become eroded after only one episode of grazing at the wrong time (e.g. after a heavy rain) or in the wrong place (e.g. when stock are allowed access to a natural waterway).

Figure 4.5: This State 2 woodland was already susceptible to erosion, but incorrect placement of this runoff diversion pipe (middle) probably made it much worse. The pipe was allowed to discharge water at a height, displacing large amounts of soil.

Extensive clearing of woodlands for grazing and other agriculture has led to a sharp increase in runoff volume and frequency, reducing the time for and ability of watercourses to revegetate and recover from minor erosion. Remnants down slope of cleared land may no longer be able to manage the extra water, resulting in eroded watercourses. The condition of land adjacent to woodland remnants is therefore important. Erosion often starts on adjacent land and moves into a woodland patch (Figure 4.5).

Pesticides and herbicides

Spray drift from herbicides used in paddocks adjacent to box gum grassy woodlands can cause death or damage to woodland vegetation. Trees, shrubs and grasses on the edge are particularly vulnerable. Herbicide drift can also delay or stop flowering and seed set. A secondary effect of herbicides can be weed invasion of bare patches left by herbicides.

The incorrect use of pesticides to control insects in cropping fields can also kill beneficial native species [65]. These native invertebrates contribute to nutrient cycling and pollination and are a food source for native wildlife.

Firewood collection

About five million tonnes of firewood is collected each year in Australia to heat households [42]. Over three quarters of this is collected from private property, and more than half of this comes from

THE BUSH STONE-CURLEW PREFERS THE MESS (BOX 4.2)

Bush stone-curlews are more often heard than seen. This is because bush stone-curlews do most of their foraging at night, eating insects, worms, frogs, spiders, lizards and sometimes, small mammals. This large (to 55 cm) bird has grey-brown plumage and big, yellow eyes. It is usually seen crouching near logs and litter or clumps of grass, or skulking around on long spindly legs and thick knees. Their plumage blends in well with logs, litter and grass, making excellent camouflage from line-of-sight predators.

Photo: Gordon Dobson
www.flickr.com/photos/peppergroyne

Because of high levels of predation, habitat destruction, firewood collection and 'tidying up' activities, the bush stone-curlew is listed as endangered in NSW and Victoria. Its preferred habitat is open forest or grassy woodland with a low, sparse understorey. Bush stone-curlews need fallen timber and tree debris on the ground for foraging, shelter and camouflage.

If you find an individual or pair of bush stone-curlews on or near your property, you can:

- retain fallen timber of all sizes and maintain large tussock grasses, litter and open spaces
- manage foxes and feral cats, and keep pets indoors at night
- establish buffer zones of unimproved pasture around woodland remnants
- avoid disturbances and grazing in spring and summer during nesting
- fence off known nesting sites.

unregulated markets [42]. Different species are preferentially collected, with river red gum, red box, ironbark and yellow box being the most favoured.

Removal of fallen timber for firewood disrupts important processes such as soil and nutrient cycling and plant establishment. It removes critical habitat for many woodland species such as birds and invertebrates, and can trigger erosion events. For these reasons, collection of fallen or standing timber is unsustainable and threatens the ecological integrity of box gum grassy woodlands.

4.2 Other edge effects

Woodland remnants do not exist in isolation. By definition, a remnant has an *edge*. Some edges are 'hard', and some are 'soft'. Hard edges contrast sharply with the remnant, for example cropping land immediately adjacent to woodland. Soft edges are those that have components similar to the woodland and that gradually change into the surrounding land use.

The physical edge itself creates climatic conditions that are different from either the middle of the adjacent paddock or the interior of the remnant. The edges of remnants tend to be warmer, drier and windier than the interior of the remnant.

Edges also tend to support their own suite of specialists, which can have negative effects on the other species in a woodland. One example is the noisy miner (*Manorina melanocephala*), a native honeyeater whose numbers have increased due to clearing (Figure 4.6). Noisy miners aggressively exclude smaller birds from their territories. As well as being edge

specialists, noisy miners tend to be more prevalent – and aggressive – in woodlands that lack a vertical structure that includes a mid-storey with shrubs of different sizes and young trees [66]. The 'edge effect' of noisy miners can penetrate up to 200 m into the woodland interior. The increasing prevalence of noisy miners in wooded areas is a significant threat to woodland birds in south-eastern Australia.

Figure 4.6: Noisy miner. Photo: Ian Michael Thomas.

Remnants of box gum grassy woodlands are also susceptible to damage from surrounding agricultural land uses. More intensive land uses and higher inputs are associated with harder edges and stronger edge effects. Smaller remnants are particularly vulnerable to the pressures exerted by adjacent land uses. Exotic species invasions, changed microclimates, increased nutrient inputs and chemical damage from agriculture, and increased runoff can often be traced to adjacent land uses. Importantly, the stresses imposed on woodlands by adjacent land use are ongoing, regardless of their intensity. Ways to recognise and mitigate the effects of adjacent land use are covered in Chapter 16.

Four generations of trees in State 3 woodland.

Chapter 5. Key points from the science

1. Box gum grassy woodlands are characterised by a diversity of vegetation layers (structure) and types of species. The main layers include a widely spaced canopy of eucalypt species; a mid-storey of younger canopy trees and sparse tall shrubs; sparse, patchy, and often prickly smaller shrubs; and a ground layer of tussock grasses with a colourful mix of forbs, leaf litter and fallen timber. The diversity and structure of this ground layer is an important part of box gum grassy woodlands ecology and conservation.
2. Disturbance has been responsible for both the formation and degradation of box gum grassy woodlands. Disturbances act on grassy woodlands at different scales of time and space. Livestock grazing, nutrient enrichment, weed invasion and changed hydrology are some of the main threats to box gum grassy woodlands.
3. Heavy or continuous livestock grazing has led to a cascade of changes in grassy woodlands. These changes include: loss of soil structure and soil invertebrates; soil compaction and poor water infiltration; erosion; weed invasion; loss of native species richness and overall diversity; and change in species composition to plants of shorter stature and less palatability.
4. Nutrient enrichment comes from livestock dung and urine, fertiliser and introduced legumes. Added nitrogen and phosphorus creates a competitive advantage for exotic weeds adapted to more fertile conditions. Nutrients can be difficult to remove and relying on natural processes can take decades.
5. Weeds are opportunistic by nature. They will colonise bare ground and thrive after disturbances. Weeds produce large quantities of seeds that remain in the soil for some time.
6. Clearing of native vegetation has changed the way water moves over, under and through the landscape. Natural salts are being brought to the soil surface in rising ground water, killing salt sensitive native plants. Saline overland flows are causing localised salinity outbreaks in degraded areas.
7. Adjacent agricultural land uses have increased the aridity of local climates, and led to damage from herbicide, pesticide and fertiliser drift. The increase in native edge-adapted species such as noisy miners has put additional stress on grassy woodlands and wildlife.
8. Box gum grassy woodlands can exist in a number of different “states”, which are related to their species composition and disturbance history. The condition of a woodland remnant can change, either for the better or for the worse. Changes for the better often result from active management or restoration, and changes for the worse are often related to maintained or increased agricultural intensification. The characteristics of each state and the drivers of transition between states have been represented in a State and Transition Model. This model is helpful for determining what activities should be curtailed and what new management may be required.

Blue devil (*Eryngium ovinum*). Photo: D. Carr

Part II: Getting Organised

With a broad understanding of the ecology of box gum grassy woodlands and some guiding principles from the preceding chapters, you're ready to get to work. Part II guides you through the process of setting objectives, planning and monitoring progress. Thoughtful planning and documentation can be as important for success as the actual on-ground works.

Chapter 6. Planning your management

6.1 Flexible management for box gum grassy woodlands

Adaptive management is the process of using trial, error, the best available information and intuition to develop – and then often change – management strategies.

ADAPTIVE MANAGEMENT AND PLANNING EMPLOY THE FOLLOWING GUIDING PRINCIPLES:

1. **Know your objective, and keep it simple**
2. **Observe before you act, take notes and adapt what you do – forever**
3. **Use the precautionary principle in your management**, but don't let lack of knowledge paralyse you
4. **Always test a small patch first**

The elements of adaptive management are represented as a plan-trial-review-do-monitor-evaluate cycle (Figure 6.1). Because you are working in an endangered ecological community and every patch of woodland is different, it is important to trial any new management techniques on a small patch before applying them at a larger scale. Planning then testing can reduce the risks inherent in using new or unfamiliar management techniques.

Figure 6.1: The adaptive management cycle for box gum grassy woodlands.

1. **Planning.** This involves identifying management issues and objectives for your grassy woodland. Then identify the available management options and select the most appropriate ones (Table 6.1). Work out a monitoring plan to determine how change will be detected and success evaluated.
2. **Trial.** Next, trial the management activity in a small area. By testing a small patch first, you will find out if

there are any unforseen obstacles or consequences of the activity. Carefully record what you do because this information will be important to determine which actions worked and which didn't.

3. **Review and fine tune.** A trial is only useful if you assess how it went, what should be done differently, and how it might scale up. Make sure to look closely at the finer details of what worked to save time and reduce risks at a larger scale.
4. **Do.** Now implement your plan for the whole site. Accurately record methods and costs as you go. It's hard to figure out what worked a few years later if you can't remember what was done in the first place.
5. **Monitor.** The time spent planning monitoring activities pays off, because you already know what to look for and how to measure it. Monitoring is simply a process of regularly recording and reviewing the results of management activities (see Chapter 7).
6. **Evaluate.** By examining monitoring records at the appropriate times, you can tell whether your management actions are meeting the desired objectives. If the on-ground results are not meeting your original objectives, then either the management activities aren't working, or you may have to wait longer. It's time to reassess, and modify management as required. You are now back to the planning phase, and the cycle begins again.

Each of the steps above should be recorded in a consistent and organised way that allows you to look back to previous records and make comparisons through time.

Using this approach may seem obvious, but adaptive management is rarely used in a formal and documented way. Unfortunately, key insights can be forgotten, new information is not used to its greatest advantage, and interactions between ecology and management may be misunderstood.

More on planning

Managing woodlands to restore or maintain condition is a complex and long-term undertaking, so careful planning is essential to make the best use of your time and resources. If you have an Environmental Stewardship contract, you may have made up to a fifteen-year commitment. If your site is very degraded, it may take longer to achieve success.

Woodland management planning is comprised of four steps:

1. **Identify what needs to be improved** in your woodland, by asking the following questions. If you are an Environmental Stewardship contract holder, your field officer will have used a similar approach to formulate the management plan that is in your contract.
   - What are the threats to maintaining the current condition?
   - What problems need to be addressed to move it from one state to another? (Chapter 4)
   - What management actions can fix these problems? (Appendix B)
   - Which actions are most urgent and which ones are easiest to achieve?
2. Based on the answers to the previous questions, **set your objectives**. What changes are expected as a result of your management activities? Make sure objectives are realistic in terms of area and timing. Set long-term objectives first, and use short-term objectives as stepping stones to help reach them.
3. **Select ways to monitor** your woodland to see if the expected changes are occurring. When are these changes likely to occur?
4. **Monitor the changes** that occur in your woodland and compare them to what was expected to happen.

Setting clear, realistic objectives

Achieving your long- and short-term objectives will require a strategy. You may need to break each objective down into smaller units, and you should first address the most urgent threats you have identified. Also, look for actions that are easy to implement and will improve the condition of your woodland patches ('no regrets' actions).

Setting clear and realistic objectives considers timing and how success will be measured. Some actions like herbicide treatment or carbohydrate addition may need to be repeated to achieve the desired outcome. Some actions may need to be taken in combination with other actions, such as using targeted herbicide applications in combination with hand weeding to remove grassy weeds in a State 1 woodland.

Some changes may be dependent upon other changes occurring first. For example, if annual grass weeds are a problem, your objectives might be:

1. Reduce soil nitrogen concentration to allow establishment of native tussocks and discourage exotic annuals. Target: 3 mg N/kg by year two.
2. Successfully establish tussocks of kangaroo grass in sites previously occupied by annual grasses. Target: seeds sown in year one have fully occupied the area by year five.
3. Build up the soil seed bank for kangaroo grass by excluding grazing when it is flowering and setting seed. Target: competition from kangaroo grass prevents annual weeds germinating by year five (seed set of remaining annuals will need to be controlled over several years, while you conduct the other activities).

6.2 Assessing what to do, and when

Managing a patch of box gum grassy woodland involves three basic strategies:

1. Maintenance (look after what you have)
2. Enhancement (improve the condition of what you have)
3. Restoration (increase the area of native vegetation through revegetation).

All three strategies can be used to improve the condition and extent of a woodland patch. The State and Transition Model in Chapter 3 gives some indication which actions are appropriate or necessary to move woodland between different states. For a patch in State 1 (grassy woodlands), it is best to maintain the patch in as good a condition as possible. For patches in States 2 or 3 (native pastures or fertilised pastures) the aim is to improve condition and shift them towards State 1 or 2. For patches in States 3 or 4 (fertilised pastures or crops and sown pastures), restoration works will often be necessary in order to transition them towards State 2 or 3.

Maintenance — looking after what you have

Maintaining the condition of a woodland patch is important no matter what state it is in, but is particularly important for woodlands in very good condition. Maintenance actions may be either passive or active. *Passive* actions are those that leave things as they are, for example:

- not removing live or dead trees
- keeping rocks and fallen timber
- not applying fertiliser
- not cultivating.

Active management will also be necessary to maintain your woodland because weeds and grazing pressure are always a threat. Examples of active maintenance include the following:

- **Fencing** of a woodland patch may be needed to control livestock and other herbivores (Box 6.1).
- **Strategic grazing** can reduce biomass to stop weeds from seeding or to reduce fire risk. Also consider the

impact of grazing by native species such as kangaroos.

- **Vigilant weed control** is important where maintenance is the main strategy.
- **Monitoring and control of feral animals** such as pigs, goats, rabbits and foxes reduces further degradation and decreases opportunities for weed invasion.
- **Managing biomass** helps maintain bare spaces between grasses and other plants so that regeneration can occur. Techniques include fire, strategic grazing, selective use of herbicides and physical thinning.

WHY FENCES AREN'T ALWAYS ENOUGH: A CLOSER LOOK (BOX 6.1)

Several researchers in south-east Australia have found that many remnants, even after fencing and stock exclusion, don't recover – that is, recruit native trees and ground cover – by themselves. Why not? Looking back to the State and Transition Model described in Chapter 3, it is quite possible that many of these remnants have in fact crossed a threshold, meaning the changes in the system are irreversible unless there is management intervention. It is likely that two different thresholds have been crossed. First, elevated nutrients from grazing or fertilisers have created a positive feedback loop that enables the exotics to perpetually outcompete the natives. In the mean time, the native seed sources have been lost, since many native seeds do not last long in the soil. Even if an area is fenced to exclude grazing, regeneration of native canopy and ground cover will continually fail until weeds are controlled and the other regeneration requirements coincide.

Enhancement – improve the condition of what you have

As there is so little box gum grassy woodland remaining in good condition, management that enhances the condition of a woodland patch is very beneficial. Most enhancement activities are active, with one exception: cessation of fertiliser in grassy woodland will gradually result in fewer nutrients in the soil and allow for greater abundance and diversity of native species. Examples of *active* enhancement include the following:

- **Nutrient management** can help move State 3 woodlands towards State 2 and 1, and make conditions less favourable for defoliating insects. Nutrient management can be achieved through strategic grazing, mining nutrients with crops or scalping away topsoil (Chapter 11).
- **Strategic grazing** can be used to enhance woodland condition, for example by reducing the biomass of exotic grasses, thus allowing light and space for other species to grow and thrive. It can also be used to provide controlled disturbance, creating space for regeneration of trees, shrubs and groundcover species (Chapter 12).
- **Fire** can be used to reduce biomass, release nutrients and stimulate germination from both the canopy and soil seed banks (Chapter 9).
- **Revegetation** can enhance the species and genetic diversity of a woodland patch, especially where there may only be a few, possibly in-bred individuals (Chapters 13 and 15).
- **Addition of habitat features** can be valuable for woodland wildlife. Features may include logs and fallen timber, water, nest boxes, litter and rocks (Chapter 17).

Restoration – increase the area of native vegetation

Where woodland remnants have been severely degraded (States 3 or 4), restoration through revegetation may be necessary. Restoration can be used to replace missing layers (e.g. add trees to a derived grassland), to increase understorey diversity or to increase the size of a woodland patch. While restoration is most appropriate in woodlands in poor condition it may also be necessary to add species or fill gaps in woodlands in good condition. Some plant species like murrnong and wild sorghum are very susceptible to grazing and are likely to be missing from all but the very best woodland patches. These species could be re-introduced through planting (Chapter 15).

Your woodland or derived native grassland is likely to be divided into different zones, according to state and cover type. Consider the management actions needed for each of these zones, as detailed in the management plan prepared by your field officer.

Appendix B outlines the management actions that may be appropriate for woodland or derived native grassland in each state, depending on the problems that need to be addressed. More detail of each management activity is provided in Part III of this handbook.

6.3 The likely future of a woodland patch

You are managing your grassy woodland to either maintain or improve it. In order to move a woodland patch to a preferred condition, you must determine what got the patch to where it is now, and what might happen under different management scenarios. What might happen if you:

1. Fence it and walk away?
2. Keep doing things exactly the same?
3. Experiment and 'get it right'?
4. Experiment and 'get it wrong'?

For any given management issue that you may face, try exploring these scenarios with your own woodland. For most box gum grassy woodlands, active management will be best, but each of the four scenarios above may end up happening somewhere on your property. This 'thought' exercise can provide important insights, such as helping you choose an appropriate management action for the right place and time, or helping you understand why a particular management action has been specified in your contract.

The following examples represent just two possible situations a woodland manager may face, and what might happen under each of the four scenarios.

Example 1

Condition of site or zone:	State 3 derived native grassland
Specific problem to be addressed:	Dominance by exotic annual grasses.
Goal for site (short term):	Increase native perennial component of grassland.
Drivers of change:	Overgrazing and fertiliser.
Scenario 1: Fence and walk away	With no further grazing or fertiliser inputs, this pasture will in the medium term become a rank, weedy site with some native grasses, and a weed source for adjacent paddocks or woodlands.
Scenario 2: Status Quo	Continued grazing and nutrient inputs maintains the exotic annual dominance. If grazing is too heavy, the pasture will shift towards unpalatable weeds (e.g. thistles, St John's wort, and Paterson's curse).
Scenario 3: Experiment and 'get it right'	Decide to let litter build up (to inhibit establishment of annuals); occasional mowing in some areas with slash retention to stop seed set of annuals; perennials begin to increase.
Scenario 4: Experiment and 'get it wrong'	Non-targeted herbicide applications and strategic grazing doesn't work; pasture remains much the same but with more bare ground.

Example 2

Condition of site or zone:	State 1
Specific problem to be addressed:	Dense kangaroo grass (KG) monoculture; grass is choking out other grasses and forbs.
Goal for site:	Reduce dominance of KG to provide gaps for other natives, especially forbs.
Drivers of change:	Lack of fire or other disturbance.
Scenario 1: Fence and walk away	KG continues to dominate; Thicket grows; Eventually (15–20 years) KG litter is so dense new plants cannot establish and sward collapses. Weeds or other natives move in.
Scenario 2: Status Quo	Probably much as above; depends on current management.
Scenario 3: Experiment and 'get it right'	Cool spring or autumn burns in selected areas with supplemental seeding of different grasses, reduces KG dominance and allows some natives to establish.
Scenario 4: Experiment and 'get it wrong'	Decided to graze whole patch because uncomfortable with burning and haven't put up temporary fencing/ water. Grazing was too heavy and too long; KG does not survive well and some weeds are able to establish.

You can see that 'failure' in these instances is problematic, but not disastrous. This scenario exercise shows the value of trialling a technique on a small area first, and the importance of management. The best outcomes will be achieved by learning from observing, reading and perhaps most importantly, from your mistakes. By employing adaptive management, you can then change management to get better outcomes.

Blackthorn (*Bursaria spinosa*). Thorns enable this native shub to persist in lower quality remnants. Photo: M. Frawley

Chapter 7. Monitoring

If you are part of the Box Gum Grassy Woodland Project, you will have received a monitoring toolkit that goes with your contractual agreement. Your Management Actions Results Table (MART) may be adequate for your monitoring needs. A Woodlands Management Log has been provided as a supplementary recording tool for you to use, copy or adapt as you wish. **The methods outlined here do not replace the monitoring you must do as part of your Environmental Stewardship contract.**

'Monitoring' is a more formal term for 'observing'. If you are an active manager of your woodland, observation will be an integral part of your work. If you are observing the plant and animal species in your patch, thinking about what to do to reach your management goals, and what to do differently if things don't go as expected, you are already employing some of the basic principles of monitoring and adaptive management.

Structured monitoring is a good way to learn how a woodland naturally changes and how it is improved as a result of your management. Woodland monitoring is just as necessary as checking the rain gauge, market prices and the bank balance.

7.1 Monitoring basics

Monitoring should be related to the objectives set for your woodland patch (Chapter 6). If the objective is to reduce or eliminate weeds, then monitor the type and abundance of weeds in your woodland. If your objective is to stimulate regeneration, monitor the number of different kinds of young trees and shrubs. If you aim to increase the diversity and abundance of wildflowers, first monitor the number of bare areas between native tussock grasses.

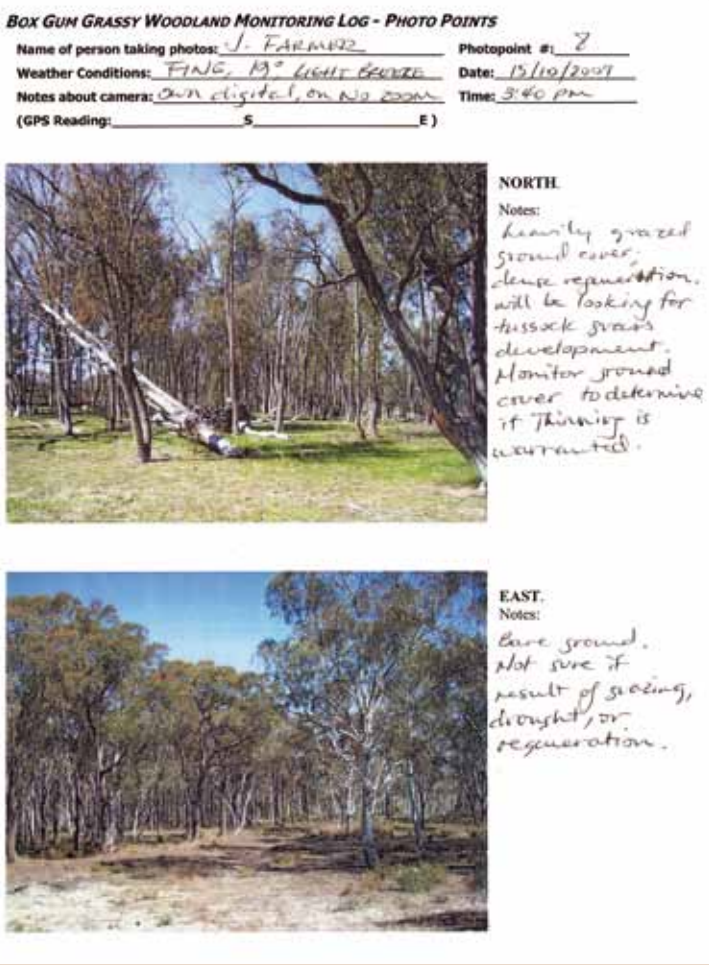
There is no single right way to monitor, and different components of the woodland will probably require different techniques. For example, bird monitoring is very different from native vegetation monitoring. There are, however, some basic rules for monitoring. These are:

1. Monitoring should be carried out at regular intervals (e.g. once or twice a year), at the same time each year. Try to pick a time when plants are actively growing and identifiable. For example, spring is a good time in winter-rainfall areas, but late summer may be preferable in summer rainfall areas.
2. Observations or measurements should be recorded in the same way each time; otherwise they cannot be compared.

'HOW CAN I POSSIBLY MONITOR GROUND COVER PLANTS IF I DON'T KNOW WHAT THEY ARE?'

Photo: L. Oliver

Figuring out what species are present, which are native and which are exotic can be challenging at first. A good idea is to start with what you don't want – weeds. Keep your field guide, a camera and some plastic bags on hand whenever you go out to the woodland, not just on monitoring days. If you can't identify something, ask someone who might know. Also expect to make some mistakes along the way. Instructions for collecting and preserving plant specimens can be found easily on the Internet. For example, the Centre for Plant Biodiversity Research has a good page on how to collect herbarium specimens (**www.anbg.gov.au/cpbr/herbarium**), as well as identification aids. Some suggestions for field guides are given in Appendix E.



BOX GUM GRASSY WOODLAND MONITORING LOG - PHOTO POINTS

Name of person taking photos: J. FARMER Photopoint #: 7

Weather Conditions: FINE, 19° LIGHT BREEZE Date: 15/10/2007

Notes about camera: OWN digital, on NO ZOOM Time: 3:40 pm

(GPS Reading: S E)

NORTH

Notes:

Heavily grazed ground cover, dense regeneration. Will be looking for tussock grass development. Monitor ground cover to determine if thinning is warranted.

EAST

Notes:

Bare ground. Not sure if result of grazing, drought, or regeneration.

Figure 7.1: A sample of a completed photo point monitoring sheet, using the template provided in Appendix D. This format can be adapted to suit your objectives.

3. Use permanent markings for photopoints, quadrats or line transects. Examples include star pickets or reinforcing bar, painted white or with bright safety caps.
4. Observations and measurements should be written down, dated and stored together safely, for future reference. This is when forms are useful.
5. Monitoring that is too complicated is monitoring that won't get done. Keep it SMART: Simple, Measurable, Achievable, Relevant, Timely.
6. Compare the information recorded on several previous occasions to detect changes or reconsider management decisions and future actions.
7. Again, monitor features that relate to objectives – what you aim to achieve.

7.2 Monitoring techniques

Photo points

Choose fixed places where photographs will do a good job recording progress. Choose a permanent point central to the management unit (or treatment area), and take four photos – one in each cardinal direction. Make sure to maintain the same focal distance each time, and take the photos at the same time(s) each year. Label the photos and directions, either electronically in a document, or on a piece of paper if using

film. Also note the management activities that have occurred or are ongoing for that site (Figure 7.1).

By themselves, the photos won't necessarily reveal much, but by comparing photos taken annually you will notice changes after a few seasons or years. An example of a photo point recording sheet is in Appendix D.

Vegetation monitoring

Walk and record method:

A walk-through survey that records plants, animals, general condition and interesting or concerning features can be very informative. Here's how it works:

1. Choose a route that efficiently covers a representative portion of the woodland or management area.
2. Using the recording sheet in Appendix D2, record the plant species that you see. Note whether they are native or exotic, abundant or scarce. Alternatively, you can use a blank sheet, or create one that already has a list of the common plant species associated with box gum grassy woodlands in your region. For example, use the species list(s) in Appendix A as a starting point. As you walk along simply place a check mark after the name of the species you see.
3. Also record any animal sightings, issues of concern such as erosion or weed infestations, unusual (rare) plants, and signs of regeneration. Be sure to note the locations of these special features.
4. Save some space on the back of the sheet to make a sketch of an interesting feature, paste a photo or draw a simple map.
5. Remember the basic rules of monitoring and record the information in the same way each time for comparisons later.

Quadrat method:

A 'quadrat' is a square area of predetermined size, often 1 m^2, within which you record features of interest. The purpose of quadrats is to obtain detailed data on ground layer plant density and species diversity, which can then be assessed against management objectives.

Choose a direction to walk, then place the quadrat at your foot say every ten paces. This will provide fairly unbiased data about what is growing in the ground layer. Use the recording sheet provided in Appendix D5, or one you create yourself. Then record the different species found in the quadrat, the number of individuals, and the approximate percentage cover. Record any mosses and lichens as well. If you don't know a particular plant, give a brief description so you can re-identify it next time. Tally the total number of species, and the amount of bare ground. Use the information from quadrat monitoring as a supplement to a walk-through survey or your fifty step walk (Environmental Stewardship contract holders).

Monitoring different animals

The different animals that are present in or adjacent to your woodland can tell you a lot about the kind of habitat your management is helping to provide. Brown treecreepers prefer mature remnant vegetation with lots of logs and litter on the ground for foraging. Their presence is an indicator of high quality habitat. On the other hand, a large population of noisy miners (especially if smaller birds seem absent) may indicate a need for better vertical structure in the woodland (Chapters 2 and 4).

Bird monitoring should be done early in the morning, when there is no rain and little wind. Monitoring in spring will detect migrating species. Bring a good bird field guide and binoculars (Appendix E). Choose a route that is central to the patch or management area. Remember to stop and just listen at the beginning and at various times during the walk. Use Appendix D2 or your notebook to record the species heard or seen. A good way to learn birds is to bring

a bird-watching mate along to help. Consider recording the birds that are in adjacent land uses for comparison

There are well over a hundred reptiles found in the box gum grassy woodlands region, including tortoises, snakes, geckos, legless lizards, skinks, dragons and goannas. Reptiles are sensitive to loss of habitat and feral predators. Active reptile searches involve turning over rocks and logs to see who's hiding underneath. Always stand on the side of the rock or log that remains on the ground then slowly and gently turn it while looking underneath. Keep a sharp eye out for those small skinks that run out quickly. If you don't know the reptile, make a mental note of its features so that you can identify it later. Slowly and gently replace the rock or log, putting it back exactly as it was. If you found a reptile, make sure it is out of the way before replacing the rock or log.

Soil monitoring and sampling

If you have a soil nutrient problem that supports abundant weeds, soil sampling can be used as a complement to vegetation monitoring. Soil condition is relative, so choose sites that concern you, plus a few that are in better condition.

Sample when soil is neither completely dry nor saturated. Soil sampling should be conducted every two to three years during the same season and in the same area. Soil samples should also be taken before conducting any nutrient management activities.

There are laboratories that you can send your soil sample to for testing. A soil-testing lab can be located through your state Department of Primary Industries, or through the Yellow Pages or the Internet. You will need to specify what characteristics you would like the lab to test for.

If you are concerned about elevated soil nutrients, start with nitrate, ammonium and available phosphorus (Chapter 11). Baseline Carbon: Nitrogen ratios can be used to check how the soil is improving for native plants. Many soil testing 'packages' also include pH and salinity (electrical conductivity) tests.

The soil sampling procedure is as follows:

- Choose the sampling sites. These could be in areas of possible nutrient enrichment, such as stock camps or the edges of fertilised paddocks. Near a quadrat is also appropriate if concerned about soil health in these areas. The total size of each site will vary, but should be homogeneous and large enough to take several soil cores.
- Permanently mark these sites for future sampling.
- Using a soil tube, soil auger, shovel or spade, remove a sample of topsoil that is about 2 cm wide and about 6–10 cm deep. Discard any leaf or organic matter.
- Collect 20–30 cores in this manner from each site, and place all the samples from each site into a separate bucket or plastic bag. For example, all 20 cores from Site 1 go into one bag, all 20 cores from Site 2 go into a second bag, and so on. You will need to spread each sample out to dry properly, so it doesn't continue any chemical reactions.
- Once the sample is dry, thoroughly mix it, then take a 300–400 g subsample of this mixture. This is the soil that will be analysed. Unused soil should be replaced, used in a soil seed bank experiment (Chapter 9) or discarded thoughtfully, considering there may be weed seed present.
- Follow the soil container and mailing instructions from the laboratory you choose.

There are several websites and services that can help to interpret test results. One of these is the NSW Department of Primary Industries, at **www.dpi.nsw.gov.au/aboutus/services/das/soils#Interpretation**.

Some general trends are as follows:

- In areas of nutrient enrichment, expect nitrate to be high compared to ammonium.

- As conditions improve, the ratio of nitrate:ammonium should slowly shift to favour ammonium.
- Similar to nitrate, phosphorus levels can also be expected to drop slowly as the plant community transitions from mostly exotic pasture to native woodlands.
- Carbon:Nitrogen in the topsoils of high quality box gum grassy woodland should be in the order of 16:1 or more.
- Potassium, pH, total carbon and magnesium will all generally be higher under trees than in open areas, but lower overall in woodlands that are in good condition compared to more degraded sites.

Monitoring a mosaic of different activities

One photo point or one vegetation transect is not enough. At any given time, you may have several small activities or trials underway, and it is good to be able to determine progress for each one. Monitoring for each management activity is important but should not be a major undertaking. Keep it simple and follow the same basic rules described above.

7.3 Where to get help

Listed below are some excellent monitoring resources for further details.

Southern NSW and general

Grassy ecosystems management kit: A guide to developing conservation management plans. The kit has some introductory material on grassy ecosystems, but mainly comprises a workbook designed to help land managers develop a conservation management plan and work program. The kit includes detailed instructions and recording sheets for a variety of monitoring techniques, such as photo points, single species monitoring, vegetation condition and animals. For your copy or more information, contact Environment ACT on 13 22 81.

Queensland and northern NSW

1. **The Queensland Murray Darling Committee** has developed a biodiversity monitoring toolkit for land managers. The toolkit is supported by a one-day training workshop to demonstrate the monitoring process. Contact the Vegetation & Biodiversity Program Regional Coordinator on 07 4637 6201 for more information.
2. The **Traprock Wool Association**'s biodiversity toolkit project includes monitoring tools designed to enable individual landholders, or groups of landholders to implement simple, efficient and realistic monitoring programs for production and biodiversity values on their property. These include pasture assessment, native vegetation and habitat assessment, habitat complexity and condition, and some animal-specific techniques. **www.traprockwool.com**. From the home page, click on 'Environment'.
3. *Managing farm bushland*. A field manual for the Northern Tablelands of NSW, by Richard Morsley and Ruth Trémont, has a series of monitoring forms and instructions that have been very popular with land managers. See Appendix E for more information on obtaining a copy of this manual.

Rangelands

Meat & Livestock Australia's **EDGE**network® Grazing Land Management workshop. In addition to developing grazing strategies for sustainable production, this workshop includes a monitoring component. Contact: 1800 993 343 or visit **www.mla.com.au/edge**.

Field guides

A list of popular field guides for birds, mammals and reptiles can be found in Appendix E.

Part III. Management

Chapter 8. Improving woodland condition

Grassy woodlands are ever changing and their management requires focused time and effort. Different patches vary in their management requirements at any one time. Some patches will require a combination of management approaches, depending on their history and condition. Start with the soil.

8.1 Improving soil structure and health

Healthy topsoil depends on good groundcover, active root growth, high levels of microbial activity and rapid water infiltration.

Many soil problems today often stem from the historical (and ongoing practice) of continuous grazing. Soil carbon – in the form of humus and organic matter – is essential for retaining soil moisture and structure. Yet since European settlement, there has been a reduction of between 50–80 per cent in surface soil organic carbon [67]. Across Australia, cultivation is responsible for the average loss of seven tonnes of topsoil for every tonne of grain produced [68].

The steps to improving soil health are:

1. First, reduce compaction.
2. Next, build up organic matter.
3. Then reduce nutrients, while also adding native plants.
4. Finally, tinker with species composition, but only if needed.

1. Reduce compaction

The aim is 'more space than stuff' – that is, soil with a low bulk density. Severely compacted soil may need to be broken up mechanically, but this may not be possible in sensitive areas. Some options to reduce soil compaction are:

- **Remove the source of compaction**: fence to control livestock grazing, and reduce total grazing pressure if it is a problem (Chapter 12). A few years of rest from grazing may be enough to reduce compaction and allow for natural regeneration of native grasses and their fibrous roots.

- **Mulching**: simply adding weed-free mulch (e.g. grass clippings, leaves, shredded bark, wood chips) or compost to compacted areas should reduce soil bulk density. Mulching is a natural way to reduce soil compaction, but may be too costly for large areas.
- **Hand aeration:** if the area of compaction is small, some breaking up of the soil can be done by hand with a mattock or pick. Follow up aeration with weed-free mulch. If compaction is only moderate, some planting can occur after breaking up the soil, at the same time as mulching.
- **Deep air-jetting and mulching**: this technique is suitable for subsurface compaction, and involves using an air jet probe connected to a compressor. The probe injects air at high pressure into the soil (to about 30–45cm) to fracture the soil. Compost is then injected into the voids made by the probe. A brand of air jet (AirSpade®) is available in Australia, but is expensive (~$4000) to purchase.
- **Cultivation followed by mulch**: cultivation actively breaks up the soil, while mulch helps retain moisture and eventually adds organic matter.

2. Build up soil organic matter

Microbes that exist in or colonise mulch or leaf litter will break down and incorporate organic matter into the soil. Aeration and infiltration will improve, making plant establishment easier. Now is the time to get something growing. Aim for good groundcover with both live plants and leaf litter. For difficult sites, try to establish a native coloniser. These pioneer plants establish easily, make lots of seed, and thrive in disturbance. Examples include wallaby grasses (*Austrodanthonia* spp.), cane wire grass (*Aristida ramosa*), windmill grass (*Chloris truncata*), red grass (*Bothriochloa macra*) and weeping grass (*Microlaena stipoides*) (Figure 8.1). These species are often found in more degraded woodlands and grasslands. In open areas, try kangaroo grass hay on a small area to see how it establishes.

Alternatively, consider a sterile hybrid nurse crop (e.g. rye and some hybrids) to get things started. The roots will improve soil structure and increase organic matter. The nurse crop fills the niche that would otherwise be occupied by annual weeds. **Do not use agricultural rye or other plants that may spread to other areas.** Follow the nurse crop with native grasses as described above, or begin nutrient management.

Figure 8.1: a) Red grass (*Bothriochloa macra*), b) Weeping grass (*Microlaena stipoides*). Illustrations: M. Bedingfield

3. Tackle nutrients while also adding natives

Once compaction has been reduced and organic matter content has improved, work to reduce or reallocate any nutrient imbalances. This will be a particular challenge in stock camps and old vehicle tracks. Detailed techniques for nutrient management are discussed in Chapter 11. If you establish perennial natives in Step 2 above, then most nutrient enrichment problems will be solved.

4. Tinker with species composition

If you have managed to kick-start the processes of building topsoil and improving soil structure, as well as get a good groundcover of native perennial grasses, you can alter the relative dominance of different grasses and add or encourage native forbs (see Section 8.4).

8.2 Managing erosion

It doesn't take much for gully erosion to become a problem. A small amount of soil disturbance in the wrong place just before a big storm can be all it takes. And erosion spreads: once unstable subsoils are exposed, water will undercut the topsoil and create canyons that are difficult to stabilise. Water seepage from saturated soils can also contribute to gully erosion.

Most of the sediment in rivers and creeks comes from exposed banks. **Removing or restricting stock access** to waterways is the first step to preventing or managing erosion. Where erosion exists and is still active, it is imperative that livestock do not have access to the area. Land & Water Australia has published *Stock and waterways*, a popular, informative and free land manager's guide to grazing and riparian areas (see Appendix E for details).

Areas upstream of the erosion should be managed to **capture and slow water flows** by:

- fencing the gully out, including land well upstream of the gully head
- planting deep-rooted perennials in belts across the direction of flow, upslope from the problem
- creating interceptor banks, being careful not to expose dispersive subsoil that can become an erosion problem in itself (see Figure 4.5)
- encouraging dense growth of perennial species along the banks of gullies if seepage is contributing to erosion
- controlling rabbits and other feral animals
- revegetating within the gully in stable areas.

Plantings can help capture sediment and further slow water flows. Natural regeneration in stable areas can be supplemented by using the low-disturbance methods of direct seeding and planting described in Chapter 15.

In places where nothing will grow and erosion risk is high, you need to find ways to capture resources and create micro-site fertility. To do this, seed-bearing brush or other mulch can be laid along the contour. Alternatively, there are special fabrics designed to control erosion (Box 8.1). For example, Jute Soil Saver ® is a mesh made of 100 per cent organic hessian fibre, and comes in bales comprised of eight long strips. The mesh captures resources, prevents further erosion and retains moisture at a micro-scale to help seeds germinate and establish. It is available directly through rural suppliers or through environmental supply companies.

Wind erosion is also a major problem in some agricultural landscapes. The best way to buffer your woodland from windborne nutrients and chemicals is to maintain groundcover in adjacent paddocks and establish shelterbelts of native trees and shrubs. Chapter 16 provides more information on creating buffers for grassy woodlands.

8.3 Managing salinity

Dryland salinity is a significant risk throughout Australia's agricultural lands [48,69]. Management of salinity is a

WHEN EXPERIMENTS GO WELL... (BOX 8.1)

Wool and prime lamb grower Neil Stuart was concerned about eroded and compacted soil behind one of his farm dams. It had been bare for ages and was slowly affecting the waterway. It seemed as if nothing would ever grow on it.

Then Neil found out about hessian mesh from an earthworks contractor. Employing the principle of creating sites for resource capture, Neil hand-broadcast native grass seed over the area in mid-autumn, then rolled out the hessian mesh bales in strips over the bare area a couple of days later. He used matting pegs (similar to tent pegs) to secure the hessian to the ground. Although laying and securing the hessian was quite labour intensive, the work has been worth the effort. The mesh has helped to retain moisture and resources at the site, and grass is sprouting wherever the hessian is in place.

matter of controlling the way water moves throughout the landscape by returning the right kinds of vegetation to the right places. Establishing more deep-rooted perennial vegetation is the first step to managing salinity.

Surface water salinity

To combat surface water salinity, the key is to reverse the degrading process that triggered the problem. Work at two different scales: the salt-affected site or scald and adjacent land uses especially upslope of the site.

In the immediate area:

- cease any grazing or further soil disturbance
- prevent waterlogging as much as possible
- improve soil condition (see Section 8.1)
- re-establish perennial native vegetation.

In the surrounding landscape, especially upslope of the problem:

- establish perennial native pastures and belts of trees and shrubs in ways that capture resources (e.g. along slope contours)
- aim for 100 per cent groundcover, 100 per cent of the time in all paddocks
- become involved with catchment planning and encourage your neighbours to increase perenniality.

For severe salt damage, salt-tolerant vegetation is needed to stabilise the soil and prevent further degradation. It may take some time before more salt-sensitive species will be able to grow at the site.

Rising groundwater salinity

Rising groundwater is rarely localised to a single property. Certain features of a farm, such as being low in the landscape with little perennial vegetation cover, increase the risk of salinity. Managing salinity caused by rising ground water is a catchment-scale task that needs to be tackled by all land managers.

Again, the core requirement is to maximise perennial, deep-rooted native vegetation wherever possible, particularly in pastures. For woodland remnants that are salt affected or at high risk for salinity, salt-

tolerant vegetation buffers are useful. For example, where water table rise is slow but risk is high, plant fast-growing buffer strips along with salt-tolerant trees.

Near remnants of high conservation value, planted species should be locally indigenous. However, in areas that are already salt-affected, your only choice may be to plant salt-tolerant natives that would not typically be found in the area. If so, make sure they are not weedy species. For example, avoid the use of exotic salt tolerant species like tall wheat grass, because they can become invasive weeds in some places. Weigh the relative risks of genetic contamination of the woodland by non-local species versus further damage due to salinity.

For sites with severe salt problems, it is possible that a critical threshold has been crossed and the prospect of restoring the area to its former state is lost [36]. In these cases, a 'novel' ecosystem must be created in order to stabilise the situation. The procedure for managing these sites is much the same as elsewhere, but the species used and the timeframes will be different.

1. First, restore function – establish plants that stabilise the soil, improve nutrient cycling and use (respire) water.
2. Using deep-rooted, salt-tolerant species, start from the edges of a saline scald and work inwards.
3. Once a salt scald has been stabilised, assess whether locally indigenous plants are likely to establish and survive.

Further reading

An excellent resource is the RIRDC publication *Trees, water and salt: an Australian guide to using trees for healthy catchments and productive farms*, edited by R. *Stirzaker,* R. Vertessy and A. Sarre. Sections of the book are available free at **rirdc.infoservices.com.au/downloads/01-086.pdf**.

8.4 Manipulating species composition

Once the soil is in good condition, salinity is absent, and weeds and erosion are under control, you are then in a position to manipulate the species composition and enhance the diversity in your woodland. Plant diversity is the foundation stone for improving biodiversity – the variety of life.

1. Keystone species: kangaroo grass and snow tussock

Historically, kangaroo grass and snow tussock were the dominant grasses throughout most of the box gum grassy woodland range. Kangaroo grass was typically found in open areas, while snow tussock was usually in shaded areas. Now these grasses are far less common. These long-lived tussock grasses protect the soil from erosion, improve water infiltration and tie up soil nutrients on site. Ways to encourage these grasses are as follows:

Snow tussock: This species is more sensitive to burning than kangaroo grass, and is especially sensitive to rabbit and kangaroo grazing in its succulent seedling stage. Reducing or eliminating grazing pressure and burning (or mowing) less frequently will favour snow tussock.

Snow tussock establishes best where there is some shade and shelter. Its narrow, fine leaves will easily dry out in full sun, wind or frost when young. Promoting snow tussock in exposed areas is therefore not recommended.

Kangaroo grass: More frequent burning will encourage kangaroo grass over snow tussock. Burning every three to six years should be adequate. More frequent fires increase the risk of soil erosion and prevent the accumulation of leaf litter needed for maintaining soil health. The use of fire is described in greater detail in Chapter 9.

Kangaroo grass swards also can be improved by mowing or crash grazing (Chapter 12) [70]. Mowing kangaroo grass swards every two to three years, without removing slash, can have similar results to burning every four to six years [71].

2. Managing the density of shrubs

Shrubs are an important component of box gum grassy woodlands when present at low densities. Patches of shrubs improve plant diversity and provide habitat for woodland birds. Where shrubs exist, they can be promoted through use of fire at intervals of about eight to fifteen years. However, shrubs are lost under frequent fire or continuous livestock grazing in grassy ecosystems. See Chapter 9 for more on fire as a management tool. Important shrubs such as wattles, indigos and heaths can be planted at low densities. See Chapter 15.

3. Encouraging forbs in inter-tussock spaces

Kangaroo grass and snow tussock swards can become too thick. Without some grazing, fire or mowing they can become rank and collapse. This situation can provide opportunities for weed invasion. Overly dense swards also can suppress native forbs, which are an important part of grassy woodland biodiversity [70,72].

Forbs grow in the gaps between grass tussocks. Opening up the canopy of grasses increases the light, water and nutrients available to forbs. Inter-tussock gaps can be created by burning, grazing or slashing (with slash removed). The need for grass biomass reduction will depend on rainfall, which species form the grass canopy, site fertility, time since last wildfire and the intensity of rabbit and kangaroo grazing. For example, high fertility grasslands in south-western Victoria require burning every one to three years in order to maintain canopy gaps large enough to recruit forbs. However, this interval is likely to be too frequent in drier and less fertile areas. Determine the appropriate interval on a site-by-site basis as follows:

A. Choose a small, manageable site (i.e. less than one hectare) that has low weed abundance and good potential for native forb recruitment and establishment. Uncultivated sites with little compaction and only sporadic past grazing are good candidates. Sites that are adjacent to areas of high native species richness are also promising.

B. Optionally, conduct a soil seed bank experiment (Box 8.2) to see what species exist in the soil seed bank.

C. Conduct a controlled, low-intensity burn in mid- to late-autumn, after any existing native plants have shed their seed (see Chapter 9).

D. Monitor the site to see how long it takes for the grass canopy to fill-in any gaps; this time could be one to several years. The number of years to dense grass cover equates to the site's recommended interval for grass biomass reduction. Also monitor what

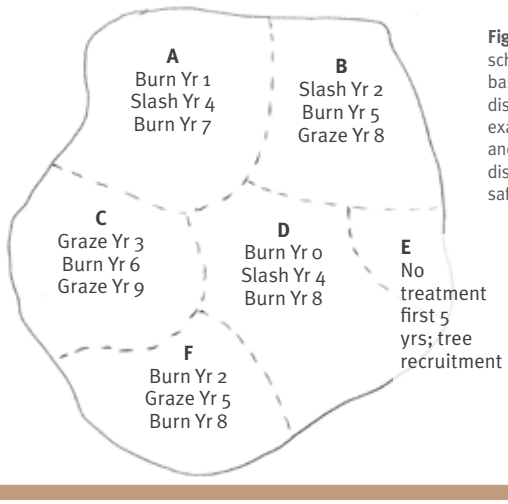


Figure 8.2: A hypothetical management schedule for opening up the grass canopy, based on a three-year interval between disturbances. Note that the timing is not exactly three years between each activity, and that Area E is being rested from disturbance until some tree seedlings are safe from fire, slashing or grazing.

WHAT'S WAITING TO GROW? BOX 8.2

CSIRO scientist Elizabeth Lindsay wanted to know what seeds were persisting in the soil seed banks of remnants and adjacent pastures in different states of degradation[73]. She took soil samples from each area, placed them in trays and watered them. As plants germinated, she assessed whether they were exotic or native, and pulled the exotics out as soon as she could identify them (or transplanted them to a separate pot).

Figures: Photo top: E. Lindsay, Photo bottom: M. Frawley

Germination followed a predictable sequence: clovers came up first, followed by rye grasses and other exotic annuals. Once these species had come up and were removed from the tray, an exciting thing started to happen: the natives, especially the forbs, started to germinate. Lindsay says she 'got heaps of lilies, and even got some orchids to grow from the soil'. Overall, more than 40 native species germinated in one tray, and she did nothing except water the soil and remove the competition. Lindsay didn't have any germinating kangaroo grass, which was not surprising, since this species does not have long-lived seeds.

Conducting your own soil seed bank experiment

Take soil cores, about 5cm wide by 5cm deep, from several areas within woodlands and pastures. Mix up the soil from each area and put it into separate seedling trays. Keep the soil moist. As plants come up, try to identify them, or transplant them to a small pot to allow them to grow big enough to identify. This method eliminates over-crowding. Continue to water and watch for as long as seeds keep germinating. If you are taking soil from a weedy area, expect weeds to come up before anything else more 'interesting'. You can also expect to find plants that are not currently growing in the patch. These plants have simply not had the right conditions for growth for a long time. If you like, try using smokewater to stimulate some of the fire-cued species as well (Chapter 14).

It appears that many of these plants are very transplantable. Lindsay put hers into her garden, and many have done extremely well without any further care or watering.

native forbs germinate and survive past the seedling stage. Different species require different gap sizes and periods of time to flower and set seed before the next establishment opportunity (disturbance).

E. If you have good success from a soil seed bank experiment (Box 8.2), native seedlings can be transplanted within the first year after disturbance; later than that and the canopy may close before the plants can adequately establish.

F. Manage for patchiness. Conduct mosaic burning or other disturbance at the determined interval (slightly more or slightly less sometimes is fine), in different areas in different years (Figure 8.2).

The above experiment should be repeated in areas where soil type, plant community, aspect, nutrient status and elevation are substantially different. Using an aerial photo with overlays for planning is a good idea (see Chapter 6). Take advantage of the weather and use low weed abundance as an opportunity to establish natives. For other methods of promoting natural regeneration, including smokewater application, see Chapter 14.

Chapter 9. Using fire

Fire is an important and often beneficial form of disturbance in box gum grassy woodlands (Chapter 4). It strongly influences plant species diversity and abundance. It is a tool for biomass control, nutrient management and species manipulation, and complements strategic grazing.

9.1 Fire basics

The key factors to consider with fire are the elements of a fire regime, managing for patchiness and landscape context.

USING FIRE TO MANAGE BOX GUM GRASSY WOODLANDS EMPLOYS THE FOLLOWING GUIDING PRINCIPLES:

2. **Manage for patchiness**
   - Manage for diversity
   - Use a diversity of management
4. **Use the precautionary principle in your management,** but don't let lack of knowledge paralyse you
5. **When trying new approaches, test a small patch first**
6. **Prevent grazing of seedlings and grazing-intolerant species**

Fire regimes

A fire regime is the pattern that fire follows in an ecosystem, and is determined by four characteristics: intensity, frequency, season and extent. **Intensity** relates to the heat or energy that is released by flames. This can be measured by flame height. Fire intensity determines how much plant material is combusted. Most prescribed (planned) burns should have flame heights of less than 1.5 meters (low to moderate intensity fire). **Frequency** is the average number of fires over a period of time, for example burning every six years. Because frequency is an average, it can be quite different from the actual inter-fire interval, which is the amount of time since the last fire. Just a couple of years between fires can kill species that haven't seeded yet. Too many decades between fire and some species can disappear without the stimulus of fire. The **season** of fire is related to fire intensity; higher intensity fires are more common in hotter, drier times of the year. This is part of the reason that many plants and animals do not flower or reproduce at this time. **Extent**, or the area that is burned, contributes to the overall management mosaic. Extent is also related to how easily a burn can be controlled.

A fire regime is not a fail-proof recipe, and fire is never a constant. Using fire is about responding to climate and the needs of particular species. For example, a fire regime that aims to promote biomass reduction and species diversity via cool autumn burns every four to six years, may need to be delayed during periods of drought, or advanced following wet years and high fuel accumulation. Similarly, if a wildfire has recently affected a site, it will reduce the need for a fire for at least a few years. The regimes have thus adapted and changed.

Mosaic burning

Never burn your whole patch at once. Smaller, patchy burns are desirable because:

- wildlife has unburned patches to escape to (refuges)
- fire-sensitive plants can re-colonise from unburnt places
- they promote diversity
- they are easier to control and reduce the risk of wildfire
- they reduce the risk of getting it totally wrong if the season or intensity of the fire doesn't achieve site objectives.

'It is well to remember that the frequency of burning by Aborigines was determined not by a time scale, but by observation of the land itself, and that the method was to burn in controlled patches, producing a mosaic of areas in different stages of fire recovery. Fuel loads did not accumulate to disastrous levels. The burns were carried out when the tuberous perennials were dormant – early autumn, when they had already shed seed, and not when they were in full vegetative growth during winter and spring. In addition, the Aborigines were able to draw on long-accumulated knowledge of weather patterns to time their burns.' Beth Gott (2006)

Burning small portions of a site creates a mosaic of patches of differing sizes and ages. Fire can be patchy in a number of ways:

- patchy in size; some burns larger than others
- patchy over space; some areas are burnt, others are not
- patchy in timing; some areas may be burnt in spring, others in autumn, and so on
- patchy in intensity; some areas may only be 'flame weeded' while others fully combusted
- patchy in frequency; for example, some grassy areas are burned about every three years, nearby wooded areas burned about every ten years.

Patchiness can be achieved through a mosaic of small fires targeted for nutrient management or aimed at promoting desirable species. Other areas could remain fire free for a longer period because they have about the right mix of species and ages.

Considering the rest of the landscape

The burning and management mosaic you create exists in the context of the surrounding landscape. What's happening outside the patch should influence management, and likewise management can have an effect on the greater landscape. For example, the use of fire may simply be too risky in a patch next to a highly flammable forest, but low risk when surrounded by cultivated paddocks. Also consider:

- avoiding burning if a wildfire has swept through the district leaving your patch unaffected— your patch is now an important refuge
- trying a spring burn if most others in the area usually burn in autumn.

Fire safety

Fire is dangerous. Make sure to take every precaution to prevent its escape. When using fire, make sure you:

- have constructed fire breaks (mown or cultivated strips)
- carry out burning when wind speed and temperature are low
- have sufficient helpers and equipment to contain the fire (water trailers, pumps, rakes etc).
- extinguish fires that get into existing trees and shrubs, particularly those with hollows (these can take 150 years to replace).

Before you conduct a burn, make sure to:

- speak to your field officer and relevant fire authorities, and alert all neighbours
- use the precautionary principle: wet standing dead trees and fallen timber.

Engage other members of the community in a planned management burn. This helps others to feel more comfortable and gain experience with prescribed fire. Make sure to have adequate public liability insurance

before conducting a planned burn. Be aware that burning is defined as a form of clearing under the NSW Native Vegetation Act. Contact your local relevant state authority for more details.

Relevant authorities by state

NSW: The NSW Rural Fire Service and the local CMA should be the first point of contact before conducting a management burn. These organisations can assist you in timing a burn and give advice for working in an Endangered Ecological Community (EEC).

Queensland: Contact your local rural fire brigade (Rural Fire Service). A planned burn requires a written permit from a fire warden. These permits are usually free of charge. See also the landowner bushfire preparation materials available from the Southeast Queensland Fire and Biodiversity Consortium. More information is at the end of this chapter.

9.2 Hot versus cool fires

Some plant species are promoted by a hotter or more intense fire, while other species are more abundant after a cool fire. Cool fires are naturally less risky.

Hot fires

Hot fires can stimulate regeneration of a range of species from the soil seed bank, including species that did not have plants present before the fire. The heat from a fire and the chemicals from smoke can break the dormancy of soil-stored seeds, particularly acacias. Hot fires are likely to influence seeds buried deeper in the soil. This effect is often seen after fallen timber has burned and a range of plants emerge from the ashes weeks later.

A hot fire can be part of a planned burn, but such fires are harder to control and pose a risk of damaging property and bushland. Hot fires are therefore not recommended as part of a woodland management portfolio.

If a hot wildfire comes through your woodland, it can be an opportunity to monitor regeneration, both of the existing species and of new plants. Many species, including eucalypts, can reshoot from dormant buds. After a hot fire, review your fire regime and make adjustments as needed, taking the rest of the landscape into account as well.

Cool fires

The term 'cool fire' refers to the season of the burn as well as to the fire's temperature. For example, burning grasses during late winter and early spring in temperate (winter rainfall) regions results in a cooler fire than in late summer and autumn.

Most prescribed burns should be low-intensity, cool fires. These fires remove above-ground herbaceous plant material without killing roots, scalding soil or damaging trees or fallen timber. As a precaution, wet fallen and standing timber before conducting a burn.

To burn green vegetation over small areas, use a weed burner (Figure 9.1). At larger scales, use steam application or a herbicide followed by burning once the plant material has browned off. Weed burners can be obtained from rural suppliers like **www.farmerswarehouse.com.au** and Farmer's Mailbox.

Figure 9.1: Weed burning at an experimental box gum grassy woodlands site. Photo: I. Lunt

Some grasses such as Coolatai grass are favoured by fire (Figure 9.2). If present, try to control such grasses by other means before using fire. Cool-season fire should also be used with great care when African lovegrass, Chilean needle grass or blady grass (*Imperata cylindrical*) is present. Follow-up herbicide treatment of these grasses may be necessary if they re-sprout after fire.

Figure 9.2: Lush regrowth of Coolatai grass shortly after a fire. Photo: D. Carr.

9.3 Season of burns

Generally speaking, most planned fire occurs in either autumn or spring. However, the best time to burn is site-specific. Timing depends on weather, season and the species that are being manipulated by fire.

When using fire to promote desirable native species, find out when the species germinate either through observation or from resources such as Florabank (see Appendix E). Use fire before but not during germination. Wait until desired natives have set seed before conducting another burn.

Spring burns

Spring burns can be useful for reducing the mass of exotic annual grasses, though they are not very effective for exotic annual broadleaf plants such as Paterson's curse and capeweed [74,75]. Spring burns can reduce seed set in exotic annuals such as wild oats (*Avena* spp.), bromes (*Bromus* spp.), quaking grasses (*Briza* spp.), rye grasses (*Lolium* spp.), barley grasses (*Hordeum* spp.) and fescues (*Vulpia* spp.).

Spring burns can also be part of a nutrient management strategy (Chapter 11). Spring burning can disrupt flowering and seed set of some native forbs and is therefore not recommended in high quality remnants.

In southeast Queensland and northern NSW there is often less rainfall over winter, resulting in higher fuel loads and temperatures for spring burns. Most bushfires in this area occur in spring, so it is a good idea to use alternatives to spring burns to control exotic annual grasses. A useful guide for ecological burns in this region is available from the Southeast Queensland Fire and Biodiversity Consortium.

Autumn burns

Autumn burns are most commonly used to encourage native species recruitment, by both re-sprouting species and those that germinate from seed. In the winter rainfall zones of box gum grassy woodlands, many land managers and fire authorities are reluctant to use fire in the autumn. Autumn burns are seen as being too hot or the risk of wildfires too high due to hotter, drier conditions. However, autumn burns are the least likely to kill desirable native species and promote germination from the soil seed bank.

9.4 Fire frequency

Burns shouldn't be too frequent. Again, this depends on management objectives, soil type, climate and time since drought or unusually wet seasons. But there are some basic rules of thumb:

1. Fire frequency in individual patches should be about every four to eight years. Remember that frequency can be different from inter-fire interval. Some intervals may be shorter than others depending on objectives and past seasonal conditions.

2. More frequent burns can, but may not always, lead to overexposure of soil, erosive processes and weed invasion (see Chapter 4).
3. Cool fires, such as those achieved with a weed burner, can be used more frequently than hotter fires that also combust litter.
4. Fires to reduce seed set of weeds will need to be more frequent than burns used to encourage the abundance and diversity of natives.

Fire that is not frequent enough can also cause problems. Build up of biomass can suppress germination and growth of other species, and can encourage the encroachment of woody weeds. The small purple pea (mountain swainson-pea; Swainsona recta) relies on fire to enhance germination and to maintain open inter-tussock spaces (Figure 9.3). The exclusion of fire, or too-infrequent fire, increases competition by other plants, including weeds, tussock grasses and sometimes black cypress-pine (in northern sites).

Figure 9.3: Small purple pea in flower.
Photo: M. Frawley

More information

- An excellent resource on using fire in Queensland can be found at **www.derm.qld.gov.au/register/poo264aa.pdf**.
- Similarly, NSW DECCW has an interesting fact sheet on fire and fire regimes in NSW bushland. **www.environment.nsw.gov.au/fire/fireandthenswbush.htm**
- NSW Rural Fire Service: 02 8741-5555, or **www.rfs.nsw.gov.au/**.
- Queensland Rural Fire Service: 07 4614 2835 (Toowoomba), or **www.ruralfire.qld.gov.au**
- Griffith University's Southeast Queensland Fire and Biodiversity Consortium offers a comprehensive set of landowner bushfire preparation materials, including an *Individual property planning fire management planning kit*, *Fire monitoring manual*, and an *Operational fire manual*. These documents are available for free at **www.griffith.edu.au**. Conduct a search for 'landowner bushfire preparation materials' in the top right corner.

Native St John's wort (*Hypericum gramineum*).
Photo: M. Frawley

Chapter 10. Weed management

Weed control should be an essential part of any whole-farm and woodland management plan.

The basic concept: managing weeds while encouraging natives.

The key to any weed management strategy is to make sure something desirable is ready to grow in the place of the weed that is removed. In many instances, simple herbicide treatments will do little either to stop annual weeds or encourage replacement by native perennials. Many weeds have very large seed stores in the soil. Altered soil nutrients favour weeds over natives (Chapters 4 and 11). Unless there is something to replace the weeds, such as a native seed source or planting, herbicide use alone is merely a bandaid.

Weeds can be blown in; carried in on shoes, hooves, fur or tyres; or deposited in dung. Weeds are opportunistic by nature, taking advantage of soil that is bare or disturbed. If your woodland or derived native grassland has a very high proportion of exotics, first aim to maximise groundcover with both living and dead plant material. The objective is to minimise bare ground and eliminate disturbances that favour weeds.

10.1 Integrated weed management

Effective weed management requires a holistic approach. Integrated management tackles weeds at the property and neighbourhood scales. Aim to make the landscape resistant to further weed invasion. This will require integrating different control techniques that target vulnerable aspects of a weed, its lifecycle or its environment [76].

WEED MANAGEMENT EMPLOYS THE FOLLOWING GUIDING PRINCIPLES

1. **Know your objective, and keep it simple**
3. **Observe before you act, take notes and adapt what you do - forever**
4. **Use the precautionary principle in your management, but don't let lack of knowledge paralyse you**
6. **Restore the basics before attempting to restore the details**
8. **Maintain groundcover**
   a. Don't create opportunities for (further) invasion
   b. Replace what you remove (when taking weeds out develop a strategy for getting natives back), but
   c. Remember that some bare ground is good to allow for native forbs to establish
13. **Use herbicide sparingly**
15. **'Quick fixes' often fail - quickly**

Planning is an essential step because weed management is a long-term process. Careful planning and persistent action should successfully reduce weeds. Sound weed planning should:

- identify the best methods and times to control weeds
- prioritise limited resources
- integrate weed control with other management (e.g. fire and nutrient management)
- ensure that inputs and results are measured against desired outcomes so that management is continuously improved (adaptive management).

Integrated weed management includes good hygiene: weed-free vehicles, livestock and mulches. Monitor perimeters and other possible points of entry.

Understanding weed ecology

The first step in an integrated weed management program involves understanding the ecology of the weeds of concern. Get to know both your weeds and the natives you are trying to encourage. Try to answer the following questions:

- When does it flower and seed?
- Is the weed associated with high nutrient levels (e.g. thistles)?
- Does its stature change when grazed? That is, can it adapt to heavy grazing by flowering at lower heights or by growing parallel to the ground?
- How does it respond to fire? For example, some broadleaf weeds and exotic perennial grasses can increase after fire.

There are several ways to answer these questions. Observation is an excellent tool, especially for determining when species flower and set seed. Good weed and native species information is also available on the Internet; see the list of weed management resources at the end of the chapter or use field guides such as those listed in Appendix E. Also refer to Chapter 3 and Chapter 4.

With these questions answered, you are in a good position to make effective management decisions. For example, Coolatai grass has a short-lived seed bank, so if you can prevent seeding for more than two years and kill the remaining plants, new establishment can be minimised. But it does spread with fire, so burning is not a good option.

Confusing species

It isn't always easy to tell a weed from a native. There are some natives that are often confused for weeds, and vice versa. If you are unsure, use the precautionary principle. Don't spray, dig, slash or burn until you are certain the plant in question is undesirable. Some commonly confused species, and how to tell them apart, are included in Appendix C.

MISTLETOE: FRIEND OR FOE? (BOX 10.1)

Mistletoes are good. Mistletoes are bad. Which is correct?

Mistletoe is an integral part of healthy forest or woodland, not necessarily a pest. Many species of birds, butterflies and moths rely or feed on the more than 85 species of native mistletoe in Australia.

Mistletoes get their water and nutrients from the host tree, but produce most of their own energy via photosynthesis. However, mistletoes can kill a tree if an infestation becomes too severe.

Photo: D. Carr

Mistletoe is a good indicator of ecosystem health. Mistletoes are generally only a problem when remnant trees are already stressed from lack of water (natural or human changes to hydrology), clearing, fertiliser, sheep camps and soil disturbance. Like the predator that targets weak prey, mistletoes are better able to infest and kill trees that are already sick or stressed.

Removing or killing mistletoe will only temporarily restore the health of a tree. Treat the cause, not just the symptom[61,77].

10.2 Weed management strategies

There are five broad approaches to managing weeds:

1. Grazing
2. Nutrient management
3. Fire
4. Physical removal
5. Herbicide

A combination of approaches will often achieve the best results. Basic management advice and photographs for common weeds, such as Chilean needle grass, serrated tussock, Coolatai grass, Paterson's curse and some others can be found in Appendix C.

1. Grazing

Grazing is an appropriate strategy in State 2 and 3 woodlands and derived native grasslands where a small amount of soil disturbance or physical disturbance is tolerable. The timing and duration of grazing for weed management are critical for success. Take care because livestock can disturb or kill native plants, cause soil compaction or spread weed seeds. Chapter 12 discusses grazing as a weed management strategy in more detail.

2. Nutrient management

Elevated soil nutrient levels are a cause of weed infestations so nutrient management is a part of successful weed control. Nutrient management works best in combination with other strategies such as burning, grazing, weed removal and native seed introduction. Details on nutrient management strategies are found in Chapter 11.

3. Fire

Cool fire can be a useful tool to help control many common weedy annual grasses. Fire is not an appropriate technique for broadleaf exotics and some exotic perennial grasses. The use of fire as a management tool is described in Chapter 9.

4. Physical removal

Good, old-fashioned **hand pulling** of weeds infesting small areas can work well and causes less soil disturbance than other methods (Box 10.2). Other options include chipping and slashing.

Chipping (or grubbing) is a popular method for managing low-level infestations of weeds like serrated tussock (*Nassella trichotoma*), and involves digging out a weed using a mattock or chip hoe. Remember to replace soil and mulch to minimise disturbance and inhibit further weed establishment.

Slashing can be done by hand or machine and should be timed to prevent seed set. Slashing by machine is not recommended in areas where natives may be damaged by machinery. Some weeds seeds are able to mature even after being slashed (e.g. nodding thistle, Paterson's curse), so only leave slash if you know that seeds will not mature.

5. Herbicide

In high quality remnants (e.g. State 1 and State 2), herbicide use should be a last resort, because the impact of herbicide on native species is a major risk. However, herbicides can be an efficient way of controlling weeds. Carefully consider the following targeted uses of herbicides.

Spray-topping: Annual weeds can be managed to prevent seed set by applying low rates of herbicide to the seed heads. Note that some plants simultaneously flower and set seed on different parts of the plant, so don't leave it too late. Perennial plants are likely to require a combination of repeated chemical and mechanical control.

Cut and paint method: This method can be used on woody weeds with stems of at least 5 mm diameter; smaller than that is a bit too tedious. This is a useful method for woody weeds like blackberry and briar rose that regrow after cutting. The method is quite simple: the weed is cut to a point five to ten cm above the ground, and the cut stump

BUSH REGENERATION: FROM METHOD TO PHILOSOPHY (BOX 10.2)

In 1971 two sisters, Joan and Eileen Bradley, wrote *Bringing Back the Bush*, a book on regenerating bushland that has since become a movement in its own right. The 'Bradley Method' of bush regeneration, as it is now called, developed over many years. The sisters started noticing that natives were replacing the weeds they had removed, and over time took notes, monitored and refined a system for removing exotic species in bushland.

Bush regeneration philosophy is based on three principles:

1. Always work from good to bad areas.
2. Disturb the soil as little as possible and restore it to its natural condition.
3. Allow the rate of regeneration to dictate the rate of clearing.

The first principle requires the ability to tell a native from a weed, so that you can tell a 'good' area from a 'bad' area.

The second principle permeates every aspect of the philosophy; from what shoes are worn to what tools to use. Hand pulling and small hand tools are preferred for all but the most difficult woody species. Soil, humus and mulch should each be replaced as nearly as possible to its original layer and condition.

The third principle requires more patience than work in most instances. Areas in good condition will regenerate more quickly than areas in poor condition. Over clearing simply invites more weeds, because the natives cannot regenerate fast enough.

'How heavily infested the bush is depends on how often it has been disturbed. The secret is in the seed bed. Undisturbed bush soil under its natural mulch is superbly resistant to weed invasion.'

The Bradley sisters' cautious, methodical and meticulous method is not without its critics. Many people feel they have neither the time nor the patience to use the Bradley Method, and there is plenty of research to suggest that some level of disturbance is good for many Australian ecosystems. However, this minimal disturbance approach may be useful in higher quality areas where careful weeding may be all that is needed to prevent deterioration. One can then move to the next best bits.

Bringing back the bush, by Joan Bradley (2002 edition), is available through New Holland Publishers. [78]

is immediately painted with the appropriate herbicide. Keep in mind the habitat that woody weeds may be providing before removing them (Box 10.3).

Stem injection: This technique can be used on woody weeds with stem diameters greater than 10 cm. Stem injection kills the plant but leaves it standing. Non-target effects are eliminated compared with externally applied herbicides. Stem injection can be done in two ways: drilling and frilling. Drilling involves drilling holes every 5 cm around the base of the tree, 4 cm deep and at a 45 degree angle. Use a squeeze bottle to fill each hole with undiluted herbicide as soon as it is drilled (Figure 10.1a). Frilling uses the same principle but involves using a sharp chisel or axe to make the cuts (Figure 10.1b). Do not ringbark the stem for either method.

Spot spraying: If other methods fail, individual weeds and small patches can be spot-sprayed using a backpack or other apparatus. This method is covered in more detail in Chapter 15.

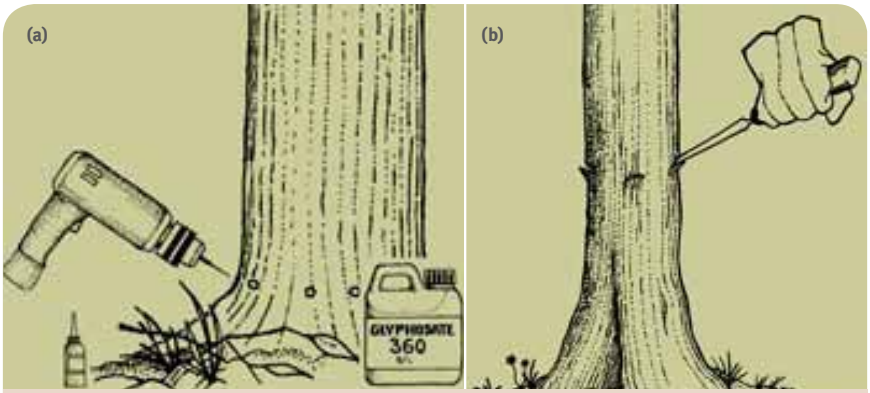


Figure 10.1: Stem injection (a) and frilling (b). Illustrations: Norman Yeend and Virginia Bear.

Herbicide use at larger scales, as part of ground preparation for revegetation activities, is covered in Chapters 14 and 15.

10.3 Managing woody weeds

Most of the shrubs in State 2 and 3 box gum grassy woodlands are, unfortunately, woody weeds. Common examples are blackberry, briar rose, African boxthorn and hawthorn. Many of these woody weeds spread through bird droppings, so are highly invasive and can form dense thickets. Again, various integrated methods are required. For example, blackberry control often requires a combination of herbicide, slashing and physical removal. The role of each of these approaches will depend on the surrounding vegetation and the density and size of the blackberry plants.

When managing woody weeds, observe before you act. The shrub may be valuable habitat. One option is to kill the plant but leave it standing while another native shrub (that you plant) is growing. See the box this page for an example.

Some people consider native shrubs like cassinias and some trees such as native pines (*Callitris* spp.) to be weeds because of their potential to form dense regrowth, spread and reduce forage. However, a low to moderate density of these plants is part of healthy, functioning grassy woodland. They should be managed and retained as habitat and to contribute to structural diversity. Managing native shrub density is discussed in Chapter 8. More information on thinning native woody vegetation is in Chapter 14.

10.4 Weed management resources

- The Australian Government **Weeds in Australia** website contains useful information on general weed management. It also has a search function for specific weeds with management advice, as well as links to publications and grant opportunities. **www.weeds.gov.au**.
- **Paddock plants workshop.** NSW Department of Primary Industries runs workshops to help land managers identify the plants in their paddocks and why they're there. Contract your local district agronomist for more information or to organise a workshop for your community.
- **Weeds of Blue Mountains bushland:** An excellent website that explains many of the methods of chemical control — useful for all bushland regenerators, not just people living in the Blue Mountains. **www.weedsbluemountainsorg.au**.

THIS IS HAWTHORN. THIS IS HABITAT. (BOX 10.3)

Hawthorn is one of several woody weeds that can establish when grazing is removed. Such weeds can be a mixed blessing. They can form dense thickets, dominate the understorey and threaten woodland regeneration. The seeds are easily spread via birds that eat the fruits.

On the other hand, in the absence of other dense and prickly native shrubs such as kangaroo thorn or sweet bursaria, shrubs like hawthorn are protective habitat for many small birds.

Before hawthorn, blackberry or briar rose are removed, consider what habitat you are removing. Employ Principle 8b: Replace what you remove (when taking weeds out, develop a strategy for getting natives back).

There are almost innumerable resources on the Internet about weeds. A simple search on-line for any given weed will bring up many useful sites. More weed-related resources are listed in Appendix E.

Blakely's red gum (*Eucalyptus blakelyi*). Illustration: M. Bedingfield

Chapter 11. Nutrient management

Getting soil nutrients right is important. It's one of the 15 basic principles for box gum grassy woodland management.

11.1 Nutrient cycling and nutrient enrichment: a closer look

Three of the most essential soil nutrients are phosphorus, nitrogen and carbon. When these nutrients get too high, they can disadvantage native plants.

Phosphorus (P)

Many native Australian plants have evolved mechanisms to cope with the commonly low P levels in Australia's ancient soils [79]. In grassy woodlands, available P tends to be slightly higher under tree canopies (3–5 mg/kg) than in open areas (1–3 mg/kg) [80].

The addition of P, usually in the form of superphosphate, disturbs the natural balance of P in the soil, and helps increase the availability of nitrogen to plants. This creates a competitive advantage for many weeds that have evolved in higher P environments [81].

Nitrogen (N)

The most usable forms of N in grassy woodlands are available nitrate and ammonium [82]. These compounds are typically low, less than 2.5 mg/kg [33] in undisturbed box gum grassy woodlands. Nitrate is usually 'locked up' in native perennial vegetation like trees and grasses, while ammonium is a short-lived by-product of microbial activity [83,84]. Thus, the N cycle in grassy woodlands is characterised by very small fluctuations in N availability. This cycle is quite different to the N cycles of annual-dominated systems, where N availability peaks in summer when annuals die and return nitrogen to the soil [70].

The N balance in grassy woodlands is easily disrupted. Available N can rise in two ways: through reallocation or addition [70,85]. Clearing reallocates N that was locked up in native plants and makes it available for crops and exotic pastures. Fertiliser, legume pastures, livestock dung and urine add N to the system. The resulting extra nitrogen cycling through the system typically leads to a rapid switch from native perennials to weedy annuals [46,85].

Interactions between N and P

P contributes to higher N loads, in at least two ways. First, it increases N mineralisation and thus its availability to plants [86,87]. Second, it improves the growth of legumes that fix N. These add even more nutrients to the soil, causing an even greater cascade of changes in groundcover from native perennials to weedy annuals [88].

Carbon (C)

The C in carbon dioxide forms the building blocks of all plant and animal material, and accumulates in soil and plant material. Undisturbed woodlands and forests of south-eastern Australia have very high amounts of C stored in them; most comes from living and dead plant material, but almost as much is in the soil [89].

Healthy box gum grassy woodlands will have a lot of C compared to N. Typical C:N ratios in box gum grassy woodlands are between 14:1 to 18:1 [33,80]. Lowering that ratio, by adding N or decreasing C, can set the woodland up for invasion by weeds and reduce overall soil health.

NUTRIENT MANAGEMENT EMPLOYS THE FOLLOWING GUIDING PRINCIPLES:

2. **Manage for patchiness**
   - Use a diversity of management
3. **Observe before you act, take notes and adapt what you do – forever**
4. **Use the Precautionary Principle**
5. **When trying new approaches, test a small patch first**
6. **Restore the basics before attempting to restore the details**
7. **Get your soil nutrient levels right**
8. **Maintain ground cover**
   - Replace what you remove (when taking weeds out develop a strategy for getting natives back)

11.2 Principles of nutrient management

In box gum grassy woodlands, aim to reduce nutrients, not add them, particularly if you have a problem with annual grasses and broadleaf weeds. Table 11.1 lists the nutrient management options for different woodland states (State 1, 2 or 3). If nutrients are too high, it is often due to a combination of both nutrient addition and reallocation.

To prevent further nutrient enrichment:

- restrict stock access
- change, reduce or eliminate fertiliser use in adjacent or upslope paddocks
- create buffers that capture nutrients before they enter the patch (see Chapter 16).

Table 11.1.
Nutrient management approaches by situation and woodland state

Method	Nutrient situation	State
Crash grazing	Addition and reallocation	2, 3
Hay cutting	Addition and reallocation	2, 3
Burning	Addition and reallocation	1, 2, 3
Carbohydrate addition	Addition and reallocation	1, 2, 3
Topsoil removal (scalping)	Addition	3, 4
No Kill cropping	Reallocation	↓ 2, 3

↓ Denotes woodlands or grasslands that are of poor quality for this State.

There are two main approaches for active nutrient management. One is physically to remove nutrients from the site, using one or a combination of means that target nutrient addition. The other is to lock them up in preferred vegetation (e.g. native tussock grass). For example, kangaroo grass is an excellent nitrogen competitor, and red grass is being trialled. Targeting nutrient reallocation usually requires a combination of techniques. Most nutrient management activities involve the introduction of native seed or seedlings (Section 11.4).

Unless otherwise noted, most of the nutrient management techniques introduced in this chapter are suitable for small areas, and should be conducted before activities such as tree and shrub planting or rock and timber addition.

11.3 Methods

Several of the options described below may be inappropriate for your situation. For example, hay cutting (mowing) is not an option where access is poor. Fallen branches and logs should not be moved in order to harvest hay. Usually, a combination of methods will provide the best results.

Crash grazing

This management option uses livestock to strip nutrients out of a remnant. Crash grazing involves getting a large number of stock into a fenced remnant, allowing them to feed intensively, then getting them out before they have a chance to camp. Keep stock weed-free and follow the instructions for crash grazing in Chapter 12.

When?

Grazing: Crash grazing should occur between late autumn and mid spring. Graze just before the weeds go to seed and while palatability and nutrient content is still high.

Seeding: Introduce native seed just before grazing and in the period before annuals begin to grow and obscure the soil. Grazing will help incorporate seed into the soil.

How?

For maximum nutrient removal, plants should be grazed to a height between five and ten centimetres. Crash grazing can be used in combination with fire (but do not graze right after fire) or with carbohydrate treatments over very small areas. Seed first, then graze, then apply carbohydrate (more on carbohydrates below).

If needed, install at least temporary fencing to keep stock in the desired area for the duration of grazing, which may only be for a day. For cattle, single line electric fencing may be sufficient. For more on fencing for crash grazing, see Chapter 12.

Hay cutting by slashing or mowing

Harvesting hay can be done when burning is impractical or as part of a combination of methods. Cutting exotic vegetation and removing the cuttings depletes the site of the nutrients from that crop of weeds. The same approach can be used on former pasture sites or sites where a percentage of the ground layer is to be retained (native grasses).

Hay cutting can be used as part of an experiment to see whether it is more or less effective than burning. Treating different areas in different years will help contribute to patchiness.

When and how often?

Harvest hay at the same time as you would conduct crash grazing (i.e. between late autumn and mid spring). Harvest every two to five years depending on management objectives, groundcover condition and whether the technique is being used in addition to fire. Sites that are also being burned will not need to be cut as frequently.

On formerly fertilised pastures, you may need to harvest several times throughout the growing season and repeat the operation over two or more seasons.

How?

In very small areas, hand slashing may be necessary, but remember to remove the cut material. When using machinery, do not move logs, rocks or other habitat features; hand slash in such areas or consider burning instead. Like crash grazing, harvest hay before the annuals have had a chance to set seed.

Burning

Weedy vegetation can be burned to reallocate nutrients back into native grasses. Burning vegetation causes a portion of N and P to be lost to the atmosphere. The burn creates favourable conditions for native seed establishment.

When and how often?

Burning should be timed so that it is too late for further establishment of exotic annuals, but before existing annuals have set seed [75]. On the southwest slopes and central west of NSW this corresponds to mid October. Nutrient management burns should be carried out for two to three consecutive years to destroy the seed crop of exotic

Figure 11.1: Sugar only versus burn only. These photos were taken on the same day at the same site. The left photo shows stunted growth of exotic broadleaf annuals and bare ground resulting from sugar application. Native perennials can establish here. The right photo shows the 'burn only' treatment. The native grasses have responded well to the fire, but so have the exotic broadleaf annuals.

annual grasses that have short-lived seed. If weed abundance is low (due to effective management or drought), you may not need to burn a third year. Take advantage of this opportunity to further establish native perennials.

Seeding: Sow native seeds after a burn, not before. The most commonly used native perennial for burned sites is kangaroo grass. A good coloniser such as red grass can also be tested for establishment.

Burns for nutrient management should be low intensity, cool fires such as those created by a weed burner (Figure 9.1). For specific information on conducting cool burns, see Chapter 9.

How?

Burns for nutrient management should be low intensity, cool fires. For specific information on conducting cool burns, see Chapter 9.

Carbohydrate addition (sweet success or carb overload?)

One of the primary reasons for persistent weed invasions is a fundamental shift in nutrient cycling [74]. Because carbohydrates contain C, adding carbohydrate (e.g. sugar or sawdust) to a site with elevated nitrate levels directly manipulates the C:N ratio.

Carbohydrate additions can reduce soil nitrate levels to create an establishment window for native, warm-season perennials such as kangaroo grass [74,90].

C-rich materials such as sugar, and sawdust to a lesser degree, cause a temporary surge in microbial activity when added to the soil [91]. Weeds are successful colonisers because they can take advantage of high nutrient availability. Adding sugar to the site gives a growth stimulus to soil microbes, which are even 'weedier' than the weeds. These microbes lock up nitrate, making it unavailable to exotic annuals (both broad leaf and grasses). The result is stunted growth of weeds and an opportunity to establish natives (Figure 11.1)[74].

Note: Carbohydrate addition does not prevent establishment of exotic annuals; it only restricts their growth. Therefore, this treatment only works when natives are seeded or transplanted into the patch. Only species like kangaroo grass with their large root systems can reduce soil nitrates in the long term.

Where?

Due to the high cost of sugar, carbohydrate addition for nutrient management and suppression of exotic annuals is only practical over small areas and relatively short time frames. Stock camps, remnant

edges and other areas where nitrogen and annual grasses may be high are good areas to focus carbohydrate addition. Experiment with sugar in a very small area to ensure there is a reduction in exotic annual grass growth. Once you have good establishment of native grasses, expand the treated area.

When?

Carbohydrate should be added when weedy annuals are growing rapidly. Broadcast kangaroo grass florets either before or after a sugar application. As long as the sugar treatments remain active, kangaroo grass will establish when it is ready. Its growth is not hindered by the lack of nitrogen and it thrives with the reduced competition from weedy annuals.

Figure 11.2: Ian Cole of NSW DECCW and Charles Sturt University applies white sugar to an experimental plot. Note the difference in plant growth where Cole stands, compared to behind him where there was no sugar treatment.

How?

In most carbohydrate addition experiments, sugar is applied at 0.5 kg per square metre every three months until the seeded target grass species have established (Figure 11.2). Repeated application is necessary because microbial activity slows down after a few months, soil nitrate levels increase and the annuals can once again thrive. Establishing a native perennial such as kangaroo grass at the site of carbohydrate addition is essential to lock up the N and prevent re-establishment of the exotic annuals. Carbohydrate addition can be continued for a short time after perennial establishment in order to ensure their competitive advantage.

Topsoil removal (scalping)

A drastic but effective way to reduce soil nutrients is to simply remove the upper layer of topsoil where most nutrients are concentrated. Scalping removes surplus nutrients in addition to any weed seed present in the soil. However, it also removes any native plants and native seed. P levels can still be high deep in the soil, so consider testing nutrient levels lower in the soil profile before removing topsoil [92]. Scalping of narrow strips is often done prior to direct seeding of shelter belts (Chapter 15).

Where?

Topsoil removal is not appropriate in any high-quality woodland (States 1 or 2), or where habitat features would be moved or destroyed.

Topsoil removal is appropriate in areas where:

- nutrient levels are very high due to a long history of grazing and fertilisation
- exotic species have persisted and dominated for some time
- erosion risk is low
- newly established native vegetation can serve as a hub for further restoration works.

When?

Coordinate topsoil removal with the availability of native seed to broadcast over the scalped area. Avoid periods before heavy rain or wind to reduce erosion risk. To minimise duration of bare ground, broadcast seed as soon as possible after topsoil removal.

How?

Scalping: Always experiment with a small patch first, until you are comfortable with the technique and get good native establishment. For a very small area, topsoil removal can be done by hand (e.g. with a hoe). For areas larger than a few square metres, use a small bobcat to push soil out of the way, or a blade behind a tractor to create a scrape. Be careful not to compact the remaining soil when scalping.

You can remove topsoil in a strip to create a buffer between a woodland remnant and a production paddock. Do not scalp a larger area than you have seed for. Begin the process of expanding your woodland by planting both grasses and the occasional tree and shrub. For more on topsoil removal and revegetation see Chapter 15.

Seeding: Start with at least one key species such as kangaroo grass, red grass or snow tussock (in shaded areas). Use a mix of species if sufficient seed is available. Distribute the seed by hand all over the scalped area, or for larger areas consider using a turf seeder (Box 15.2). Rainfall will firm the seed into the soil and germination will occur at different times for different species.

Where do I put the scalped topsoil?

The topsoil that has been removed is full of N, P and weed seed. Options for disposing of the removed soil include:

1. disposal at the tip or green waste dump
2. sterilising it yourself — wet the soil and cover it with plastic sheeting for four weeks. Turn the soil over, and cover it for another four weeks.
3. spreading it in a production paddock, far from the woodland, if you can tolerate the weedy annuals
4. using a small amount to run a seed bank experiment (Box 8.2).

No Kill and Pasture Cropping

Pasture Cropping is a relatively new technique that sows annual cereals (often oats) directly into perennial pastures. Pasture Cropping involves no ploughing or cultivation, thereby minimising inputs, soil disturbance and damage to perennial pasture plants. Some selective broadleaf herbicide or fertiliser applications may be used with Pasture Cropping. Pasture Cropping increases the density and vigour of summer active perennial grasses. The annual cool season crop is grown when these summer active perennials are dormant (Figure 11.3). The crop helps maintain groundcover throughout the year, can increase soil C levels and can improve soil structure. The benefits of Pasture Cropping for nutrient and weed management can be four-fold:

- Harvesting the crop directly removes nutrients.
- The crop grows instead of cool season weeds, preventing their seed set and eventually exhausting the weed seed bank.
- The dense litter from the crop inhibits weed establishment.
- An increase in soil C levels improves the C:N ratio for natives.

Figure 11.3: Native perennial grasses emerging under oats in Pasture Cropping. Photo: D. Freudenberger

No Kill Cropping is similar to Pasture Cropping, but does not use herbicide or fertiliser. To minimise soil disturbance and damage to perennials, the No Kill technique uses only disc seeders to sow a crop and only sows when the soil is dry. There is no fallow period and grazing complements the technique. Dry sowing gives the crop a competitive advantage, minimises compaction effects and uses less fuel.

When is No Kill or Pasture Cropping appropriate?

As your objective is to manage nutrients and weeds for conservation purposes, crop yield is secondary. The low input costs of No Kill or Pasture Cropping mean that these are low risk techniques.

Where?

No Kill Cropping is a good option in State 3 derived native grasslands, where there is still a native grass component but also lots of annual weeds. If all goes well, No Kill Cropping should become unnecessary as the native perennial component of the grassland achieves dominance. The seeding machinery used in No Kill Cropping is pulled with a ute or tractor, so it is not appropriate on sites that are wooded or that have rocky outcrops or fallen timber.

How?

For more information on pasture and No Kill Cropping, see **www.pasturecropping.com**

Two-day courses on Pasture and No Kill Cropping are available from **The Advanced Pasture Cropping Company,** Bonview, Wellington, NSW, 2820. For more information phone 02 6846 6393, fax 02 6846 6337 or email **angus@pasturecropping.com** or **danielle@pasturecropping.com**.

11.4 Seeding for nutrient management

In most instances, nutrient management sites can be re-seeded by hand broadcasting, which is quick and efficient over small areas, and creates a natural look.

Species should be sown in their preferred microclimates. In open areas, use kangaroo grass or a combination of kangaroo grass and red grass. In shaded areas, use snow tussock with or without red grass. Experiment with which species work for your site. Kangaroo grass and other native perennials should germinate in mid spring when annuals are usually seeding.

Seed preparation and seeding rates

Most of the information presented here comes from the Restoring Woodland Understoreys research project being conducted near Albury, NSW through Charles Sturt University. These seeding rates are high to ensure establishment, but lower rates may work. Seed coating (pelleting) and other treatments can be provided by some seed supply companies or by Seed Solutions (**www.seedsol.com**; 03 9775 1313).

Kangaroo grass

Seed should be applied by hand as 'florets' (seed mixed with chaff) at a rate of up to 35 kg of florets per hectare. While this sounds a lot, that's only about 3.5 g/m^2, and translates to around 32 germinating seeds per square metre. Establishment success will depend on seed viability and climatic conditions. You may need to re-seed (but at lower rates) in subsequent years.

Snow tussock

Snow tussock seed can be coated with a water-absorbing chemical, which increases weight slightly but increases germination rates. Snow tussock can be sown at a rate of between 1.6 kg and 2.8 kg/ha (1.6 g to 2.8 g/m^2, coated weight).

Red grass

This species is an alternative or complement to kangaroo grass because it is a good coloniser, grows well in shade and is grazing tolerant. Red grass seed should be applied by hand in pelleted form (Figure 11.4). Pelleted seed resists mould and predation better than naked seed, and is heavier, enabling better soil-seed contact. Red grass seeding rates are about 1.6 kg of pelleted seed per hectare, or 160 mg per m^2.

Figure 11.4: Pelleted red grass ready to be hand-broadcast at a sugar and burning trial in Albury, NSW.

Chapter 15 provides more information on hand broadcasting, other seeding strategies and seed preparation. Further information can also be found in *Grassed up – guidelines for revegetating with Australian native grasses*, available from **www.dpi.nsw.gov.au** (click on 'G' in the A–Z index).

A bucket of kangaroo grass florets.

Native flax (*Linum marginale*).
Illustration: M. Bedingfield

Chapter 12. Strategic livestock grazing and management of other herbivores

Grazing has a mixed effect on box gum grassy woodlands. Woodlands have evolved with a degree of grazing; yet too much grazing, especially in combination with other intensive practices such as fertiliser use and legume addition, can damage grassy woodlands [61].

12.1 Production grazing v. conservation grazing

Instead of thinking of your woodland as the means to growing healthy, sellable livestock, consider livestock grazing as a tool for producing healthy woodlands and quality pastures. In turn, stock that graze native pastures have fewer health problems and are more drought-resistant [88].

Grazing is a tool that can be used to achieve various outcomes in your grassy woodland. Whether grazing to control weeds, to control biomass or to manipulate species composition or sward structure, there are some recurring principles for conservation grazing.

Observe before you act

Observe the impacts grazing has on the diversity, types and heights of plants present in your patch. Careful observation and an understanding of the system are the essential starting point. For example, observe what happens when stock are excluded from areas with a high diversity of small native forbs and grasses. This might result in large tussocks that smother the small plants. Here, grazing exclusion may not be the best approach. When grazing is excluded from weedy areas, exclusion may promote large native tussock grasses that out-compete annual grasses and broadleaf weeds. Areas that have never been grazed should still have grazing excluded from them unless tussock grasses appear rank and deep leaf litter is smothering small native forbs.

Graze to promote diversity

If your goal is a greater diversity of ground-feeding birds and native wildflowers, try some light and intermittent grazing to open up the spaces between tussocks. For species that require large tussock grasses, grazing should be excluded and occasional patchy fire considered.

STRATEGIC GRAZING EMPLOYS THE FOLLOWING GUIDING PRINCIPLES:

1. **Know your objective, and keep it simple**
2. **Manage for patchiness**
   - Manage for diversity
   - Use a diversity of management
3. **Observe before you act, take notes and adapt what you do – forever**
6. **Restore the basics before attempting to restore the details**
8. **Maintain groundcover**
   - Don't create opportunities for further invasion
9. **Prevent grazing of seedlings and grazing intolerant species**
15. **'Quick fixes' often fail – quickly**

Keep it patchy

Some species like rufous bettongs require tall tussock grasses for protection and survival (Figure 12.1). Other species, such as birds that eat seed and insects, prefer shorter and smaller grasses with a well-formed mid-storey of shrubs and young trees. The size of a remnant will dictate to what degree you are able to create diversity across scales. Manage for patchiness.

Figure 12.1: These rufous bettongs use large tussock grasses, fallen branches or rocks for their nest sites. They are most likely to be found and survive where tall tussock grasses, some shrubs and other places of refuge are abundant. Photo: S. Alexander

How?

Each property and each woodland or grassland remnant is different. Grazing needs to be carefully planned and tailored to each situation. The two main approaches to conservation grazing in grassy woodlands are high intensity, short-duration rotational grazing and crash grazing.

High intensity, short-duration rotational grazing provides long recovery times for desired species, and is a good option if grasslands make up a significant part of your enterprise. This grazing system uses smaller paddocks to graze a large mob for a relatively short time (one to two weeks). High intensity, short-duration grazing tends to create even pasture utilisation, and favours grasses over forbs. Making the switch to high intensity, short-duration

'I JUST LET IT GO'... AND IT WENT AWAY (BOX 12.1)

Farmer Gary Johnson is managing more than 85 per cent of his farm under an Environmental Stewardship agreement. Nearly two thirds of this area is derived native grassland, mostly State 3. One of Gary's aims is 100 per cent cover, 100 per cent of the time. Not long ago, one paddock was an annual blanket of purple, thanks to the Paterson's curse. Gary tried to graze-out the Paterson's curse when it was in flower. The results were not as he had hoped. This approach merely bared the ground, creating the perfect conditions for Paterson's curse to grow back even more vigorously the next year. So Gary focused on building litter instead, letting the Paterson's curse grow and die back naturally. The dead Paterson's curse made great litter! The Paterson's curse is not gone, but is very significantly reduced. The paddock is now a mixture of exotic annuals and native perennials, including brome, red grass, spear grass, wallaby grass, Microlaena, windmill grasses and others.

Across his farm, Gary's strategy of building up litter to increase ground cover is helping to naturally restore and increase the abundance of native perennials.

This State 3 derived natural grassland was a blanket of purple two years prior.
Left: Gary Johnson demonstrates what 100 per cent groundcover looks like.
Right: the grassland now. Paterson's curse is still present, but native perennials and litter are quickly taking its place.

grazing over a property requires time, training and additional resources such as fencing and watering points. The pay-off is improved year-round forage supply, improved perennial cover and better drought preparedness. Sources of more information on high intensity, short-duration grazing are listed at the end of the chapter.

Crash grazing involves a large mob of stock in an even smaller area, for a very short time (a few hours to a day). The aim is to get the stock in and out before they are able to graze selectively and leave behind lots of dung and urine in camps. Crash grazing should be based on amount of feed (so as not to overgraze), the ecological requirements of the species you want to promote and the weaknesses of undesired species (Box 12.2). Fencing for crash grazing is covered in Section 12.5.

Don't expect immediate results. More fertile sites will respond to grazing management more quickly — whether good or bad. Carefully plan the timing of grazing, but be prepared to adjust for unexpected weather conditions.

12.2 Grazing to control weeds

Herbicides are often the first thing we reach for when tackling weeds. Admittedly, there are some weeds that are too invasive and risky to manage without some use of herbicide. If a patch has a lot of weeds plus some natives, grazing is a good option for weed control when used in combination with other management activities [93]. Grazing at the right time, and allowing adequate recovery periods for the species you do want, can be an effective way to control weeds. In high-quality woodlands, only use animals that have been in paddocks without invasive weeds.

There are two key principles to follow when grazing to control weeds.

1. **Maintain groundcover: aim for 100 per cent groundcover, 100 per cent of the time.**

   Complete groundcover includes living and dead material (litter). Litter acts as mulch and contributes to nutrient cycling while inhibiting the growth of weeds. This principle may seem to contradict other recommendations to open up the spaces between tussocks to encourage forbs. But remember Principle 6: Restore the basics before attempting to restore the details.

2. **Graze for the species you want to promote.**

   Use grazing (or not, when appropriate) to give natives the advantage.

The idea of grazing a weed into the ground may seem logical, but is generally not very effective when there are other weeds just waiting to take its place (Box 12.1). Grazing for the species you want to promote considers and responds to the times when all plant species are particularly sensitive, including:

- germination
- flowering and seeding
- periods of recovery from stressors such as drought, herbicide or fire.

The first priority is to protect desired native plants when they are most sensitive to grazing [94]. Protection from grazing during vulnerable periods helps desirable species reproduce and become better competitors against weeds. Strategic grazing then tries to take advantage of times when weed species are most sensitive. Do not graze weeds so hard as to create bare ground. Only create bare ground once weeds are under control.

Timing of grazing to control weeds

First, get to know your weeds. Appendix C provides a guide to identifying common grassy woodland weeds and provides grazing strategies for weed control. Here are a couple of detailed examples of how grazing can be used to control weeds.

Example 1. Controlling annual exotics

Figure 12.2 is a seasonal overview of grazing to control annual exotics. This diagram has been modified from the Land, Water and Wool program. Any seasonal differences in your region should be taken into consideration.

1. If groundcover can be maintained, crash graze or burn when the flowering stems of annual grasses begin to grow. Action must be early enough to allow natives to begin to grow, but late enough to prevent new establishment of exotics.
2. No grazing from early summer allows native grasses to seed and regain their dominance.
3. Light grazing or spelling helps to maintain groundcover through to the autumn break, which restricts germination and establishment of annual grasses after the break.
4. More frequent rotational grazing pressure in winter maintains the cover, vigour and competitiveness of native grasses. A dense groundcover restricts tillering of annual grasses and reduces the number of seed heads they produce.

Example 2. Suggestions for controlling serrated tussock in a kangaroo grass or other summer-active sward [94]

There is little overlap in the timing of flowering and seeding of serrated tussock, compared to kangaroo grass, so this strategy can maximise its effect on each species (Figure 12.3).

1. Rest and crash grazing in late spring to reduce seed set of serrated tussock (or low rate of glyphosate).
2. Rest over summer to allow kangaroo grass or other summer -active grasses to grow, set seed and establish.
3. Rest over autumn/winter until serrated tussock seedlings can be grazed again (possible when sub clover is present).
4. Use spot spraying or chipping to manage individual serrated tussocks.

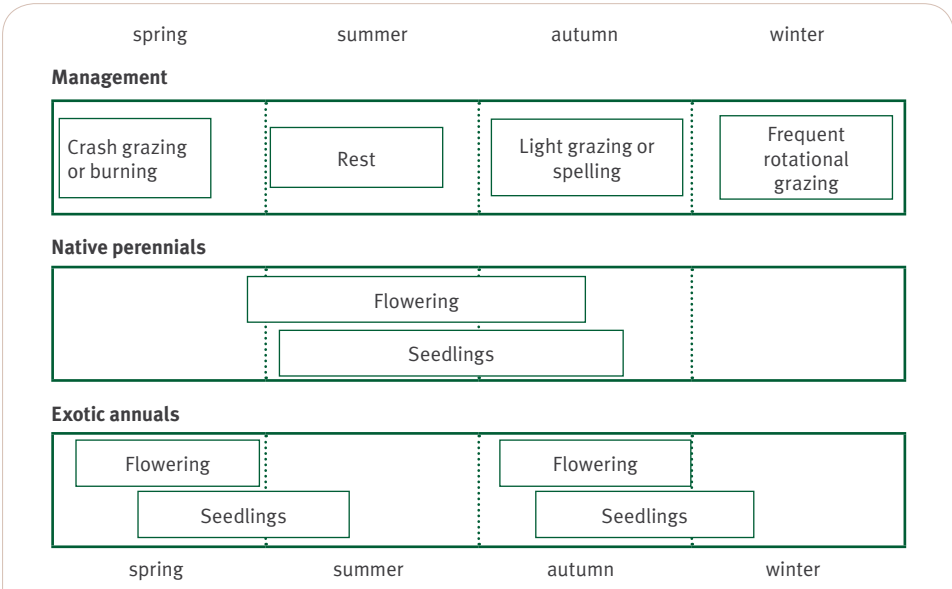


Figure 12.2: A seasonal grazing strategy to control annual weeds.

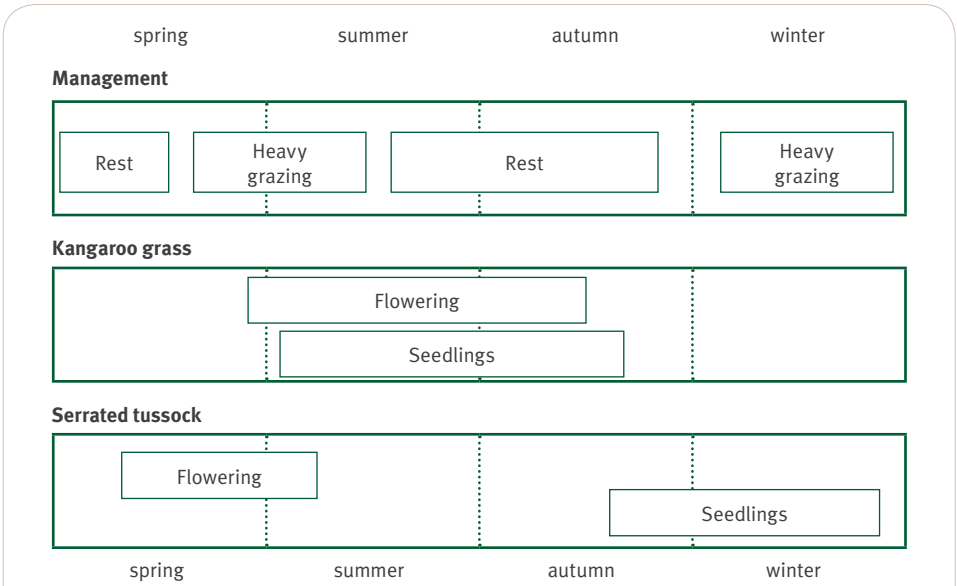


Figure 12.3: A seasonal grazing strategy to control serrated tussock.

SCIENCE UNDERNEATH (BOX 12.2)

Grass roots and grass leaves are a mirror of one another; there is about as much root mass as living leaves aboveground. When grasses are grazed, the roots self-prune (sometimes within one or two hours) to match the amount of green material above ground [95]. Although the pruning conserves energy and adds organic matter to the soil for a new flush of growth, it can weaken the plant. Fewer and shallower roots mean less access to soil water during dry times and less root mass to quickly take advantage of passing rain storms.

Selective grazing by livestock results in short palatable grasses and tall unpalatable weeds. This translates to fewer roots and weaker desired plants, and more massive roots and stronger undesired plants. The weeds now have the competitive advantage, especially for accessing water. If grazing has left any bare ground, the weeds will have an easier time establishing in these spaces.

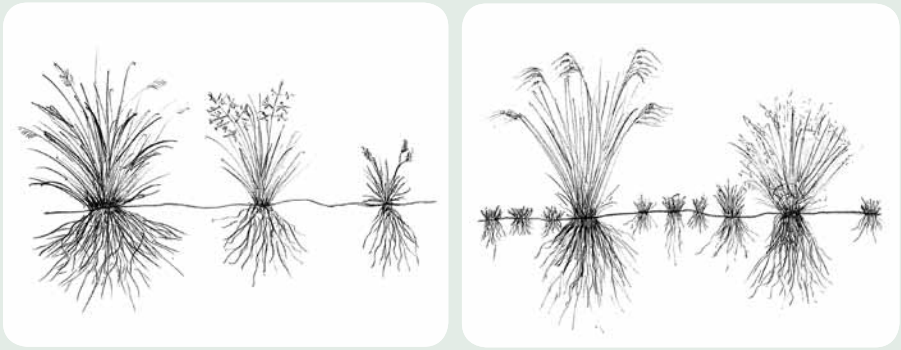


Figure: How grazing and self-pruning of roots correlate. Left: Root mass is a mirror of above ground plant material. Right: When the most palatable or desirable species are continually grazed, the less desirable species have the competitive advantage for water and nutrients.

12.3 Grazing to control biomass and promote native species diversity

'For biodiversity, the structural diversity of vegetation should be maximised, and tall and medium tussock-forming species should dominate the perennial grass layer.' [88]

What is biomass control?

In box gum grassy woodlands, tussock grasses that have not been grazed, burned or slashed for many years can prevent the establishment of other plants such as forbs. Litter build-up around perennial tussock grasses can also lead to grass death. Biomass control is the intentional removal of aboveground vegetation from a grassy woodland to reduce these risks and achieve conservation, production or fuel reduction objectives. Biomass control should be considered only when other problems such as excess nutrients or weed infestations have been solved. It is important to keep biomass control patchy, as some animals rely on thick vegetation.

Methods of controlling biomass to encourage or enhance native plant diversity include slashing, mowing, grazing and burning. Slashing and mowing employ the same principles as grazing and can be used where grazing is inappropriate, or where livestock are not available. Burning for biomass control and native species diversity is discussed in Chapter 9.

Grazing, slashing and mowing for biomass control are not very different in practice from their use in nutrient management (Chapter 11). Because biomass control aims to open up the grass canopy to allow light and space for other species to grow, removal of slash and of stock before camping is appropriate but not strictly necessary. Grazing should be intense enough to remove most of the standing grass biomass, without allowing animals time to select and overgraze preferred species. Equipment should be cleaned before mowing high quality sites to reduce the risk of accidentally introducing weed species.

In areas of high native species diversity, graze any time to reduce tussock dominance but rest in spring and summer to allow native forbs to flower, set seed and replenish root reserves.

Integrated strategies

Grazing and burning can be combined to control biomass and reduce wildfire risk. For example Aboriginal people's burning practices, and some marsupial grazing and digging were the historical means of controlling biomass levels. Burns were located and timed (typically in late autumn) to maximise regeneration of tubers such as murrnong and yellow star (*Hypoxis vaginata*), and other staple food sources. These species are likely to be damaged by livestock if grazing is permitted during their growth stages (winter and spring). However, because of the risks of wildfire in autumn, swards can be grazed or slashed before further biomass reduction burns.

Regeneration of overstorey species

Grazing can also be used to encourage the regeneration of canopy species. There are two key signals for natural regeneration success: dense flowering followed by good seed set of trees, and a wet soil profile. When these signals are present, grazing can be used to create small bare patches and a receptive seedbed. The details for fostering natural regeneration are discussed in Chapter 14.

12.4 Managing total grazing pressure

Even without livestock grazing, the combined grazing pressure of native and feral animals can lead to overgrazing and degradation. The combined effect of grazing by livestock, native and feral animals is called total grazing pressure.

Different animals behave and graze in different ways. Grey kangaroos tend to feed in large mobs, whereas wallabies and wallaroos typically feed in much smaller family groups. This means that overall grazing pressure will be higher from kangaroos than from wallabies. Nutritional requirements and preferred feed are also different [94]. For example, the feed requirements of a kangaroo are a little under two thirds that of a sheep due to the smaller size and slower metabolism of a kangaroo. This equates to about 0.6 dry sheep equivalents (DSE). Rabbits have a DSE rating of 0.125, so it takes eight rabbits to consume as much as one sheep. But rabbits reproduce like... rabbits, so one rabbit is rarely ever the problem. In terms of feed preference, sheep and kangaroos are more selective than cattle and prefer higher quality feed. Goats tend to prefer the more fibrous species.

Strategies for managing total grazing pressure

Where plenty of food and water are available, total grazing pressure will often be high. Where water is limited, fewer animals will be able to graze an area for an extended period of time. Dams are often put in or near woodland areas due to the shade provided. Consider who you are providing water for in your woodland patch. By changing the availability of water, you can influence who occupies and grazes a woodland patch.

Changing water availability

Some of the options for changing water availability are creating alternative water sources, efficient trough layouts, pumps, piping and tanks (Box 12.3). Creating or altering a watering system can be expensive and requires careful consideration as part of whole-farm planning. However, there are many benefits to improving watering systems, including:

- cleaner water
- greater flexibility
- greater control over stock and grazing patterns
- reduced mustering times
- better overall health of riparian areas.

Lethal control

Reducing numbers of grazers in natural ways by fencing and removing watering points should be attempted before lethal control. But if these controls are inadequate, you may need to consider lethal control. Kangaroos are protected species and shooting requires licences from various authorities.

Control of rabbit grazing will likely require a combination of fencing and lethal control. Environmental Stewardship contract holders must obtain permission to conduct mechanical ripping or use of explosives to destroy rabbit warrens in Stewardship sites. Please consult your field officer for more information.

12.5 Fencing

Fencing is the most common way to control where and when livestock graze. Excluding stock from sensitive areas such as box gum grassy woodlands and riparian areas helps to minimise soil disturbance and gives native plants a chance to grow and reproduce. It is important to bear in mind that fences alone will not necessarily improve the condition of your woodland,

but are one part of a complete management strategy (Box 6.1).

More fencing means more flexibility. To create greater patchiness in a large grassy woodland, fencing off smaller 'paddocks' can create areas that can be grazed at different times and intensities. The use of temporary solar-powered electric fences to subdivide larger paddocks is one approach to promote patchiness and flexibility (Box 12.4).

Fence designs for different animals

Livestock are the easiest animals to control — many effective fence designs exist for different kinds of stock. Controlling the movement of native and feral animals can be more challenging. Some fences are designed to keep livestock where they ought to be, while at the same time excluding or allowing passage of other animals. For example, 'kangaroo gates' can be built into existing stock fences at a point where kangaroos tend to pass over or under. Rabbit fencing usually requires burial of mesh wire to at least 15 cm under the ground, or bent on the ground in the direction of approaching rabbits. A maximum mesh opening of three centimetres is ideal to prevent juvenile rabbits passing through.

Fencing is always a compromise. Total grazing pressure needs to be controlled, but fencing can be dangerous to non-target animals. More than 75 species of animals, including raptors, bats, possums and gliders can become entangled and killed in barbed wire (Figure 12.4)

WATER WITHOUT DAMS? (BOX 12.3)

Dams are the most common way to water stock. However, dams are not portable, can lead to erosion problems, dramatically alter natural water flows, and attract animals other than stock.

Fewer dams do not necessarily mean less water or flexibility. Farmer Gary Johnson uses high intensity, short-duration rotational grazing on his property, 'Tulangi'. One of the main limitations for Gary's rotational grazing style is stock watering. To solve this problem, he recently invested in laying 10 km of poly pipe, which will service most of his property. The cost to lay the pipe was about $75 (2009) per hectare, or the equivalent of 25 new dams. However, the pipeline will provide many more potential watering points, and only when they are required, which means fewer unwanted grazers. The pipe doesn't take away any productive land, and is easily altered.

Gary is also improving the usefulness of his existing dams by cleaning and deepening them. Deeper, colder dams reduce evaporation and algal growth.

Top image: Watering point riser. Middle: Solar panel and pump to service piping. Bottom: Portable watering trough. Photos: G. Johnson

Figure 12.4: Squirrel glider entangled and killed on a barbed wire fence. Photo: P. Ryan

Here are several ways to make new and existing fences more 'wildlife friendly'.

- When fencing a remnant, use plain instead of barbed wire.
- To resolve most wildlife casualties, replace barbed wire on the top two strands of a fence with plain wire.
- Use night-visible fencing material, such as Borderline® or Knightline®, in high-risk areas such as around woodlands and wetlands.
- Consider using temporary fencing near high-risk areas that are not grazed often.

THE SHORTEST MILE: FAST, EFFECTIVE TEMPORARY FENCING (BOX 12.4)

When it's time to move stock into a new paddock, Ann and Gary Johnson can run 1300 m of poly-wire electric fencing in one hour.

There are 28 permanent paddocks on Tulangi, but each of them has been subdivided to enable rotational grazing. Before moving stock, Gary creates a small grazing paddock by running a single line of poly wire between permanent steel posts. The single wire is electrified by solar panels and is effective at keeping cattle in the paddock.

- Move fencing further away from wetlands to allow wetland birds like cranes enough space to take off and land.

Finding fence designs

The Australian Government has published a *Catalogue of fence designs*, which includes multiple fence designs for pigs, goats, foxes, dingoes and combinations of feral animals. The catalogue is the second part of a 2004 publication titled *Cost effective feral animal exclusion fencing for areas of high conservation value in Australia*. This publication is available on-line at **www.environment.gov.au/biodiversity/invasive/publications/animal-fencing.html**.

Two kangaroo fence designs can be found at **www.dec.wa.gov.au**. From this page, type 'kangaroo fencing' into the search window in the top left. *Fauna Note No. 32* should be the first result; click on this title to download.

Further reading and resources

1. *Managing and conserving grassy woodlands* (2002) is an invaluable resource for any manager of grassy woodlands. Information about obtaining a copy is in Appendix E.
2. **The proceedings of the Bushcare Grassy Landscapes Conference (1999)** contains a wealth of information about grazing and grassland management. The full contents can be accessed at: **www.environment.gov.au/land/publications/grasscon.html**.
3. High-intensity, short-duration rotational grazing is one of several tools used by Holistic Management practitioners. More information about Holistic Management can be found at **www.holisticmanagement.org**.
4. Different grazing options for biodiversity and production are discussed on the AgBiodiversity website **www.agbiodiversity.net/tabid/101/Default.aspx**.
5. **Stipa Native Grasses Association** Inc. promotes and demonstrates the profitable management of native grasslands for resilient ecological health. This landholder group can provide advice about Australian native grasses, their use and identification. Visit their website at **www.stipa.com.au**.
6. Chapter 7 of the *Native vegetation guide for the Riverina: notes for managers on its management and revegetation*, by Charles Sturt University (2002) specifically and thoroughly focuses on grazing management. It is available for free from **www.csu.edu.au/herbarium/riverina/**, under 'Review articles', or by contacting the Murray CMA.
7. The Land, Water & Wool program has many useful resources for managing native pastures. The program seeks to optimise both biodiversity and production, rather than taking a strictly conservation perspective. Find more information at **lwa.gov.au/programs/land-water-and-wool**.
8. **Meat & Livestock Australia**'s EDGE*network®* Grazing Land Management workshop. This workshop helps develop sustainable production grazing strategies. Contact: 1800 993 343 or visit **www.mla.com.au/edge**.

Chapter 13. Revegetation and regeneration — overview

When certain trees, shrubs, grasses or forbs are missing or scarce in your woodland, revegetation and regeneration can greatly improve its condition and assist in moving the woodland to a more desirable state. Revegetation is the introduction of seed or seedlings. Regeneration is the establishment of plants from seed held in the canopy or in the soil seed bank. Planting and regeneration techniques are summarised below to help you decide which ones are most appropriate for your situation.

Deciding on the best method

The advantages and disadvantages of natural regeneration, seedling transplants (also known as tubestock planting) and direct seeding are outlined in Table 13.1. Choice of method depends largely on the vegetation condition, soil type, climate and the vegetation layer you are aiming to re-establish. Details for these methods are provided in Chapters 14 and 15.

Table 13.1.
The advantages (+) and disadvantages (-) of the three plant establishment techniques

Natural regeneration	Tubestock planting	Direct seeding
(+) Lowest establishment costs	(-) Higher establishment costs	(+) Lower establishment costs
(-) May have to wait for a long time for results	(+) Revegetation is quick and visible to passers by	(-) May have to wait three to five years for results
(+) Natural spacing	(-) Often results in rows of plants —unnatural spacing	(+) Natural spacing and more diversely structured
(+) Establishes healthiest plants	(-) May get poor root formation caused by root spiralling in the plant pot	(+) Establishes healthier plants
(+) Plants are well-adapted to the site	(-) Adaptation to site depends on seed source	(+) Plants that germinate will be well adapted to the site
(+) Uses naturally available seed	(+) Uses small quantities of seed	(-) Uses lots of seed
(+) Requires little labour	(-) Requires significantly more labour	(+/-) Requires moderate labour
(-) Long establishment times may lead to more maintenance such as weed control	(+) Distinct rows can make maintenance easier (e.g. weed control)	(-) Longer establishment times may lead to more maintenance such as weed control
Other considerations		
(+) 'Missing' species may re-establish from soil seed bank	(+) Immediate results	(-) Most vulnerable to climate variability
(-) Needs an adjacent or nearby seed source	(+/-) Fairly uniform establishment and growth	(-) Ants can take seed or some areas may be very dense

Wherever possible, low disturbance techniques should be used (Table 13.2). However, in many situations, methods that require high levels of soil disturbance are often quicker and cheaper, allowing larger areas to be effectively revegetated. If in doubt, always err on the side of low disturbance.

Table 13.2. The role of low v. high disturbance techniques

Low disturbance techniques for States 1, 2 and some State 3		
Assisted regeneration	**Seedlings**	**Direct seeding**
Cool fire	Spot planting with mattock or plug planter	Niche or spot seeding
Smoke-water spray	Auger planting	Brush mulching
Controlled grazing	Small area (node) plantings	Hand broadcast
Spot herbicide treatment		Clay balls or coated seeds
		Small area (node) seeding
High disturbance techniques for State 4, 5 and some State 3		
Assisted Regeneration	**Seedlings**	**Direct seeding**
Cultivation	Deep ripping	Disc or scalping seeders
Scalping	Cultivation	Mouldboard ploughing
Blanket herbicide spray	Mounding	Scalping and turf seeding
	Long fallow	
	Mechanical planters	

Table 13.3 suggests the best technique for increasing the diversity of trees, grasses and forbs depending on the existing conditions of the site. Sites with an exotic or highly disturbed mid-storey and ground layer (e.g. lower State 3 and State 4) will usually require high disturbance methods such as soil cultivation or scalping. When the ground layer is in good condition, low-disturbance methods should be used for restoration. These methods are best suited to box gum grassy woodlands in State 1 (grassy woodlands), State 2 (native pastures) and sometimes State 3 (fertilised pastures).

Table 13.3. Recommended level of disturbance based on site condition

Revegetation aim	**Condition**	**Preferred technique**
Site needs more trees and shrubs	Ground layer is in good condition	Low disturbance
	Ground layer is dominated by exotics	High disturbance
Site needs grasses and ground layer plants	Mature trees and shrubs present	High disturbance outside canopy drip line
	No or few trees and shrubs	High disturbance
Site needs increased species diversity in ground layer	Ground layer is in good condition	Low disturbance

In areas where mature flowering trees exist, natural regeneration should be favoured over tree planting which carries risks such as genetic contamination of the remnant community and weed invasion due to planting-related soil disturbance[10].

Chapter 14. Improving natural regeneration

All plants in a grassy woodland will die of old age or stress. This is not a problem if each plant regenerates from seed naturally distributed on the site. Regeneration relies on seed stored in the soil or in the canopy, or seed transported to the site by water, wind or animals. However, significant natural regeneration events may occur as infrequently as every ten to twenty years, especially for eucalypts. Some of the reasons for the infrequency of regeneration events are:

- Most eucalypts do not produce large quantities of seed every year.
- Eucalypt seeds do not compete well in dense litter or with most grasses for light and moisture.
- Eucalypt seeds are very small and do not survive for a long time in the soil.
- Exclusion of stock does not account for other grazing animals, which may destroy seedlings.
- Parent trees can release chemicals from their roots that inhibit germination and seedling establishment (allelopathy).
- Most ground layer plants produce seed once a year, and will produce no seed at all if they are continually grazed.
- Some form of disturbance is usually required for regeneration of ground layer species.

Grazing regimes, fire suppression and weedy exotic plants all inhibit natural regeneration. For example, research in the Lachlan Catchment of NSW showed that natural regeneration of canopy species only occurred in about twenty per cent of woodland patches. Most of these sites are either ungrazed or subject to high-intensity, short duration grazing [41].

IMPROVING NATURAL REGENERATION EMPLOYS THE FOLLOWING GUIDING PRINCIPLES:

1. **Know your objective, and keep it simple**
2. **Manage for patchiness**
   - Manage for diversity
3. **Observe before you act, take notes and adapt what you do – forever**
7. **Get your soil nutrient levels right**
9. **Prevent grazing of seedlings and grazing intolerant species**

14.1 Five key conditions for natural regeneration

When natural regeneration is unlikely to occur on its own, it can be assisted if the following five critical conditions are in place.

1. Healthy and abundant seed

Natural regeneration requires a source of healthy seed. Plants need pollination, sufficient parent plants in the population to avoid inbreeding, and suitable conditions for growth to produce a large crop of viable seeds. Isolated trees suffering from insect attack and drought are unlikely to produce a viable crop of seed.

The viability of seed usually declines once released from the parent plant, with some species losing seed viability rapidly (e.g. *Bursaria, Dianella*), and others remaining viable in the soil for a very long time (e.g. *Acacia*).

2. Receptive seedbed

Most native seeds need contact with moist, weed-free mineral earth if they are to germinate successfully. Therefore, there needs to be some bare ground. Even in State 1 woodlands, rank tussock grasses may occupy all of the space, out-competing

other grasses and forbs, and leaving no space for regeneration. Thus, some form of disturbance is required to create gaps in the ground layer. Various methods to create a suitably disturbed seedbed are described later in the chapter.

3. Reduced competition

If moisture is limited, new seedlings will not be able to compete with established plants and will die. Tree recruitment is more likely on sites that have native perennial grasses and less likely on sites with exotic annual grasses and forbs [93,96]. Weed control is therefore critical to the success of natural regeneration.

4. Favourable climatic conditions

Climate cannot be manipulated for natural regeneration, but managers can make sure that a receptive seedbed and reduced competition are present when the climate is right. Most plants release their seed in seasonal conditions that ensure the highest chance of success, such as when it is warm and wet. Other plants have dormancy mechanisms, so that soil-stored seeds can wait for these conditions.

Newly germinated seedlings are vulnerable to drying out, so surface roughness that reduces wind speed or holds moisture will increase their chances of survival. That's why recently burned or grazed tussocks are important for successful regeneration.

5. Protection

Ants and other thieves remove or destroy seeds. Fungi or pathogens may cause germination failure. Seeds that do germinate are susceptible to browsing and grazing by all sorts of creatures from the very small (e.g. red-legged earth mites) to the very large (e.g. cattle and horses).

Fencing that excludes browsers can help, but only improves the likelihood of tree regeneration after removal of other factors that inhibit regeneration (e.g. a high density of exotic annual grasses and forbs, elevated nutrients, soil compaction) [93,96] (Box 6.1).

14.2 Regeneration methods

Assisted regeneration is most effective where good quality remnant bush is adjacent to or near the site and where regular management or monitoring is possible. Time your activities to coincide with the presence of ripe seed in the canopy and optimal climatic conditions. Higher than average summer rainfall is a strong trigger for eucalypt regeneration in woodlands, so be prepared to act quickly if this occurs.

Disturbance is necessary to open up patches of bare soil for regeneration and should occur about every three to ten years to maintain a diversity of species. The following methods are designed to create disturbances conducive to natural regeneration. Always consider low-disturbance methods first.

Low-disturbance natural regeneration methods

Cool fire

Cool burns can be used to create a receptive seedbed for regeneration. The objective is to burn smothering dead grass material, but not heat the soil beyond the surface. Fire creates gaps where seed can fall to germinate and reduces competition from existing plants. It also releases nutrients from the plants, creating a nutrient-rich ash-bed for young seedlings.

Cool burns as a tool for promoting natural regeneration should be conducted every five to six years. The whole woodland patch should not be burnt in one go. Instead, burn a mosaic of small patches (less than one hectare) joined by large unburnt patches. This reduces the impact on fauna and lowers the risk of making a mistake. For more information on when and how to conduct a burn, see Chapter 9.

Smokewater

The chemicals in smoke can trigger the germination of many Australian species, including some that lie dormant in the soil. In woodland patches where it is not possible to use fire, smokewater products can replicate the effects of fire. Smokewater is produced by bubbling smoke from burning native vegetation through water. The water traps the active chemicals, and can then be used as a spray. Smokewater can be produced with a simple apparatus[97], or can be purchased from commercial suppliers (e.g. Regen 2000®; **www.tecnica.com.au**). Nindethana Seed Service (**www.nindethana.iinet.net.au**; 08 9844 3533) also provides smoked vermiculite and smoked paper discs for seed germination.

Smokewater can be sprayed onto the ground using a backpack or tank spray rig. All that is needed is a highly diluted light spray that just moistens the ground surface. Smokewater must be integrated with weed and biomass control and only used when soil moisture and temperatures are suitable for germination, generally late winter and early spring in temperate regions or spring and early summer in sub-tropical regions. Keep in mind that smokewater can also trigger germination of weed species such as thistles from soil-stored seeds.

Controlled grazing and mowing

The use of grazing or mowing is a relatively low-disturbance way to reduce over-abundant groundcover and encourage regeneration. The disturbance created by hooves can also create germination niches for seed falling onto the ground. Grazing must not be continuous. Only part of a woodland should be grazed or mowed at any one time. See Chapter 12 for more details.

Spot or strip herbicide application

In sites with few trees, but a dense groundcover (States 2, 3 and 4) herbicides can be used to create spots or strips of bare ground where tree and shrub seeds can more readily germinate.

As a general rule, spots should be created on the downwind side of existing trees and shrubs, at a distance of one and one-half times the height of the parent plant. Mow spots or strips first, then use glyphosate herbicide on grass as it actively re-grows. Spots or strips can be left as they are, or roughened with a hand tool such as a rake-hoe or mattock. As an alternative to herbicide, plants can be removed in spots with a mattock, or dense mulch mats made of plastic or hessian fibre can be laid down for a few months then removed.

High-disturbance natural regeneration methods

Cultivation

In woodland patches where there are scattered trees and the ground layer is dominated by exotics or cultivated crops (States 3 and 4), cultivation can create a seedbed for tree and shrub seed held in the canopy. Cultivation can be used to plough-in existing weeds leaving exposed mineral earth to build up soil moisture and provide a suitable seedbed. Cultivate downwind of and up to the 'drip line' (outside edge of the canopy) of existing parent trees as this is where most seed will fall. Time your cultivation to coincide with the presence of ripe seed on the trees. Keep weeds under control and monitor the site.

This technique can be used in paddocks adjoining existing healthy woodland patches to allow the patch to increase in size through regeneration. The fence around the woodland patch should be moved out to enclose the cultivated area.

Scalping

Aim to remove 25–50 mm of topsoil to remove weeds, their seeds and surplus nutrients. A grader blade or offset discs can be used for scalping (Figure 14.1). The soil should be removed from the site and redistributed where the weed seeds and nutrients will not have an impact on woodland vegetation. A single application

of a knock-down herbicide may be sufficient to kill any weeds that germinate after the scalp. If possible, use a set of harrows behind the scalping implement to create a rough surface for seed to fall or wash into. A mouldboard plough can be used to create furrows across the slope.

Figure 14.1: Topsoil scalping to control weeds prior to direct seeding. Photo: P. Gibson Roy

In highly erodible soils or on slopes, cultivation and scalping should be done across the slope, retaining strips of grass at regular intervals to catch sediment and slow down surface water.

Blanket herbicide

In patches where there is a high density of exotic grasses between scattered trees and shrubs, it may be best to use a blanket application of herbicide. Some vigorous perennial grasses, such as phalaris, will require repeated applications of herbicide. The resulting bare soil creates a more favourable environment for germination and growth of tree and shrubs seeds, but also creates an ideal site for further weed colonisation. Therefore, this approach should only be used in limited areas when trees and shrubs have ripe seed present and ready to fall. A combination of mechanical removal by cultivation and repeated herbicide application will be necessary on some vigorous grasses such as Coolatai grass.

14.3 Managing dense regeneration

Regeneration is a sign of a healthy woodland that has the capacity to maintain itself well into the future. In the absence of shrubs, the foliage of dense regrowth can serve as excellent bird habitat. Sometimes, however, regeneration is too successful, particularly in the northern region of box gum grassy woodlands. Many tree species will regenerate prolifically if conditions are ideal, resulting in dense stands of small trees. These stands should self-thin over many decades, but this is unlikely to occur within the next ten to twenty years. Some species such as white cypress-pine even 'lock up'. That is, they stop growing when only a metre or two in height (Figure 14.2).

Figure 14.2: Dense Callitris regeneration ready to be thinned. Photo: D. Carr

Dense regeneration can be a problem because:

- Trees compete with each other for light, water and nutrients, and put on height more than breadth.
- Dense, young trees out-compete grassy understorey for light, water and nutrients, leading to bare ground and erosion risk particularly if there is little litter fall or the adjacent land has high runoff rates.
- Suppressed tree growth results in fewer food resources for wildlife and means hollows take longer to develop.

Where dense regeneration causes these problems, patchy thinning can be beneficial. Fewer young trees have advantages over a high density of small trees. For example, the abundance and diversity of tree hollows increases with tree size. Larger trees often flower more profusely and at a younger age. Reduced competition results in less bare ground and a greater diversity of understorey plants.

Laws and permits for clearing native vegetation

Management of dense regeneration (e.g. regrowth) is covered by legislation. In NSW, a helpful interpretation of the regulations affecting management of regeneration is provided by the Environmental Defender's Office through a booklet called *Rural landholder's guide to environmental law in NSW* (2008). This can be obtained on-line at: **www.edo.org.au/edonsw/site/pdf/pubs/rural_landholders_2nd_ed.pdf** or by calling the Environmental Defender's Office in Sydney on 02 9262 6989.

The Queensland Government Department of Environment and Resource Management (DERM) has a *Landholders' guide to vegetation clearing applications*, which is available through their website or by contacting them directly. Fees apply for thinning permits in Queensland. DERM is contactable at **www.nrw.qld.gov.au** or phone 13 13 04. The Regional Vegetation Management Codes are available at: **www.nrw.qld.gov.au/vegetation/regional_codes.html**.

Thinning – how to do it

Always err on the side of caution. Tree density estimates for grassy woodlands are about 30 mature trees per hectare; however, many seedlings and young trees die over time to end up with this spacing. Leave enough trees to cover future losses to storms, disease, termites, fire and wind. For small trees (less than 10 cm diameter at breast height), leave at least 400 stems per hectare (approximately 5 x 5 m spacing). For larger trees, thin to no less than 250 stems per ha (6 x 7 m spacing).

Try to retain representation of different species at similar ratios to a quality remnant. Also, consider the resources different trees provide. For example, different tree species flower at different times, which can provide nectar for wildlife throughout the year.

Judge the urgency of thinning by the state of the groundcover (Figure 14.3). If trees are so dense that they are creating bare ground, they should be thinned as a priority. Leave a few dense patches throughout your woodland, as these can provide cover for wildlife in the absence of shrubs.

Figure 14.3: This dense stand of yellow box retains good groundcover in the form of litter and grasses. These trees will 'sort themselves out' over time, but thinning may be warranted to allow faster growth and resource provision.

Be aware that thinning dense stands with bare ground underneath will create opportunities for weed colonisation. Kangaroo grass and snow tussock are good species to occupy bare sites. Red grass (*Bothriochloa* spp.) is also an excellent native coloniser that has the potential to enhance depleted soils [46].

Dense stands of cypress-pines (*Callitris*) and wattles can form following high summer rainfall, fire or heavy grazing. These species are usually minor components of the tree and shrub layer so when thinning them, leave scattered individuals throughout the woodland.

Methods

Avoid using thinning methods that cause high levels of disturbance, such as removal with heavy machinery. Most trees can be removed by cutting through the trunk about 10cm above the ground and painting the cut stump with undiluted glyphosate herbicide. *Callitris* does not need to be painted with herbicide because it does not re-shoot from the stump. Cuts can be made with a handsaw, a chainsaw or a heavy-duty brushcutter. Heavy-duty brushcutters are the best option for thinning trees up to 10 cm basal diameter.

Stem injection with appropriate herbicides is an option for thinning larger trees. A cut is made in the bark of the tree to reveal the cambium layer, and herbicide is applied as a measured dose from a backpack with a hose (such as an old drench pack). Another form of stem injection is described in Chapter 10.

After cutting, thinned material should be spread around the site on the ground. Lay the branches across the slope, starting with areas of bare soil. The branches act to trap soil, litter and seed washing down the slope. Thinnings also act as habitat for ground-dwelling fauna. In dense cypress regeneration, laying cut material across bare ground can prevent weed establishment and slow new cypress regeneration events. If you have surplus thinned material, it can be added to other patches requiring additional habitat or erosion control (Chapter 17). Do not create piles of cut trees.

Native plantain (*Plantago varia*). Illustration: M. Bedingfield

Chapter 15. Tubestock planting and direct seeding

15.1 General principles for revegetation

The following ten broad principles apply to all woodland restoration projects and emerge from extensive field experience and research into cost-effective woodland restoration [98].

1. Build soil moisture before planting

Access to moisture throughout the soil profile is essential to the survival and growth of young plants. The best way to build and retain soil moisture is by increasing organic matter in the soil. However, on sites dominated by exotic plants, it may be better to keep rip lines or planting sites weed free for at least 12 months before planting. Mulching the planting spot will stop water evaporating from the soil surface. New plants should be watered if the top few centimetres of soil are dry. In low-disturbance sites, time plantings for the wettest part of the year.

2. Eliminate weed competition for at least two years after planting

Weeds compete with newly established plants for moisture. Many weeds are much more efficient at drawing moisture from the soil than new seedlings, so reduced growth or plant death usually results. Plants that struggle in the first few years of life never reach their full potential or growth rate. Weeds should be controlled around new plants for at least two years after planting to ensure the plants are vigorous enough to out-compete weeds.

3. Select the right species and provenance

Choose species that occur locally or in similar soil-landscape environments. It is not realistic to restore all species that may have occurred on a site because of limitations of seed collection, propagation and establishment. Select species that are important for the wildlife that use the woodland patch or that prevent erosion or disturbance by weeds. Seed for the plants should come from healthy populations growing on similar sites.

4. Use only high quality seed

Using seed of poor physical or genetic quality will result in poor germination, poor growth, lower resistance to diseases and pests, an inability to adapt to climate change and environmental shocks, an inability to self-regenerate and reduced diversity. Quality seed will greatly increase the chances that long-term restoration goals can be met, as well as short-term budget and survival goals. Seed supply should be planned well in advance of planting to ensure sufficient quantity, diversity and quality.

While it is important to collect seed of local provenance, it is more important to collect seed with high levels of genetic diversity. Currently accepted best practice includes:

- Seed source sites should have similar rainfall, soil, altitude, aspect and slope position to your own site. This will ensure the specimens will be adapted to the environment of the planting site. Collect from several sites if necessary.
- Collect a little bit of seed from many plants (at least twenty, but ideally fifty) of each species.
- Collect from plants that are spaced three plant-heights apart (for a 20 m tall tree, that's 60 m; for forbs 20 cm high, that's 60 cm). This prevents the collection of too many closely related seeds.

- Store collected seed in a cool dry place until you are ready to use it. This will ensure the maximum number germinate when they are sown.

For detailed advice on seed collection methods, seed drying and storage, and techniques for particular species, see the Florabank website (**www.florabank.org.au**).

5. Plant in the correct season to minimise heat stress and water deficit

Planting season will vary across the box gum grassy woodland range, and will depend on a balance between stored moisture, minimum germination temperatures, post-planting air temperature, rainfall and humidity. Seek local advice about the best time for planting seedlings or sowing seed. An overview of planting seasons is located in Chapter 15.

6. Only use healthy seedlings that meet specifications

The size and root structure of seedlings is critical to their short and long term survival. Poor root development in the nursery can result in early death, slow growth, instability in windy conditions and long-term self-strangulation. Choose seedlings with root systems that fill their containers, without spiralling or growing out of the pot base. The shoot should be about two to three times the size of the roots.

7. Ensure adequate ground preparation

Ground preparation techniques are used to soften the soil and increase water infiltration, root area and soil aeration. Many plantings will fail if the recommended ground preparation is not followed. If using high-disturbance techniques, make sure the soil has had plenty of time to settle before planting, otherwise air pockets in the soil can lead to seedling death.

8. Protect seedlings from browsing and grazing until they are tall enough to resist damage

Young seedlings are palatable to a wide range of mammal, bird and insect predators. Browsing or grazing can kill seedlings or substantially delay their growth. Continued defoliation is likely to affect growth permanently. Potential grazers and browsers should be identified before planting and controlled or managed through guarding, fencing, shooting, poisoning, warren ripping or other appropriate measures. See Chapter 12 for more information on total grazing pressure.

9. Soil nutrients, particularly nitrogen and phosphorus, should be depleted before planting to resist re-invasion by exotic weeds

Many weeds are favoured by high soil fertility and will continue to reinvade restoration sites unless nutrients are controlled. Techniques to remove nutrients include grazing, fire, weed harvest, scalping, sugar application and mining nutrients through crops. The subsequent establishment of dense native grass swards (e.g. kangaroo grass) will continue to lock up nutrients, making them unavailable to weeds. For more information on nutrient management, consult Chapter 11.

10. Ongoing site monitoring

Monitoring allows you to manage problems as they arise. Monitor weed growth, pests and diseases, seed germination, plant growth and plant survival for the first few years after planting. After the initial establishment phase, monitor competition between species, plant structure and use of the site by wildlife. Chapter 7 covers monitoring in more detail.

Practical ways to implement these principles are provided below.

15.2 Successful tubestock planting

Seedlings come from a 'soft' nursery environment but are planted into a harsh reality of competition, moisture and temperature extremes. Their survival and growth can be improved through weed control, ground preparation, protection from grazing and hardening-off. If planted according to the best methods available, seedlings will grow quickly and there should be a high survival of planted seedlings in all but the very worst drought years.

GROWING YOUR OWN SEEDLINGS (BOX 15.1)

You may wish to try growing your own seedlings of trees, shrubs, grasses or other ground layer plants. Seedling trays, pots, potting mix, a shadehouse and a reliable, quality water supply are needed. More information can be found in Appendix E and in the following books.

Growing Australian native plants from seed, by M. Ralph (2003). 2nd edition.

From seeds to leaves, by Doug and Robin Stewart (2000).

Photo: D. Carr

Most tree nurseries will have a good selection of local tree and shrub species. However, obtaining seedlings for grasses and forbs can be problematic because many groundcover species are difficult to grow or there is little demand. If so, collaborate with a nursery in your district. Assist them with seed supply and give them plenty of notice: as much as two years to work out how to grow tricky species. Grasses are more commonly grown than other plants, so you may be able to revegetate with a range of grasses, then add other species later as they become more readily available.

The following specific planting methods follow the 10 revegetation principles outlined above.

Low-disturbance planting methods

In areas where the ground layer is in good condition (State 1 or 2), disturbance should be minimised. First, think about the number and spacing of the plants you wish to introduce. For example, woodland trees are often at low densities, while grasses and forbs are at very high densities (Chapter 2). An individual species of ground layer plant may be widely scattered or in dense patches throughout the woodland.

Spot planting

Hand spot planting

- Prepare weed-free bare areas.
- If using a shovel, mattock or trowel, dig each hole one and a half times the depth of the seedling root ball and two to five times the width. For instance, a seedling grown in a Hiko tray (Figure 15.1) will have a root ball 75 mm deep and 50 mm wide; it should have a planting hole approximately 120 mm deep and 200 mm across.
- Seedlings should be well watered the day before planting. Fill the hole with water and let it drain away before planting the seedling. To remove seedlings in individual tubes, squeeze the sides, then support the stem and top of the tube while turning it upside-down and shaking. Use clean, sharp scissors or a knife to remove roots that protrude from the bottom and are preventing seedling removal.
- The top of the seedling's potting mix should sit just below the original ground level and the soil around the root ball should be firmed-up.

TREE GUARDS (BOX 15.2)

Tree guards come in many shapes and sizes. They are used for two main purposes: to protect young seedlings from browsing or grazing, and to create a more favourable micro-climate for growth.

Milk or juice cartons supported by two bamboo or wooden stakes are often sufficient. Clear plastic guards, supported by three stakes are slightly more expensive, but let in more light and result in better growth. Rigid plastic guards supported by a single stake are appropriate where sites are exposed to heavy grazing by kangaroos and wallabies. Wire or plastic mesh guards are useful where rabbit or hare browsing is the major problem.

When using tree guards, bury the base slightly below the soil surface. Guards should be removed once the plant is established or one year after planting.

Photo: D. Carr

Figure 15.1: Hiko seedling tray. Photo: D. Carr

Figure 15.2: Hamilton Tree Planter. Photo: D. Carr

Using specialised plug-removing tools

- Alternatively, try a tool that cuts a plug of soil the exact shape of the seedling root ball. For example, the Hamilton tree planter (Figure 15.2) is designed to cut a plug the shape of a forestry tube, while others are available for Hiko cells and other container sizes (Figure 15.3).
- If the tool leaves a polished side to the planting hole, use a stick or a tent peg to scratch grooves on the sides of the hole to promote lateral root growth.

Plug-removing tools cause much less disturbance than a mattock and shovel, but may be difficult to use in sandy, rocky or dry soils.

Figure 15.3: a) Create weed-free bare areas using a rake-hoe and b) mattock. c) This Hiko planter cuts a plug the size of a Hiko tray cell. d) The seedling can now be planted. Photos: D. Carr

After planting

- Return any leaf litter or mulch over the disturbed soil, leaving a gap of at least 10 cm around the stem.
- Where there is enough soil, form a dish around the plant to direct rain towards the plant.
- Water most new plantings immediately, to improve the contact between the roots and the soil and remove any air pockets. Use one to two litres of water per plant.
- Dry soil or hot and windy conditions will require repeated watering over several weeks. Naturally, it is better to plant into a fully moist soil profile.
- If working in small areas use mulch to keep soil moist and suppress weeds around new plantings. Use organic material that has a high carbon content, such as woodchips, leaf litter, bark or hot-composted municipal green waste. Ensure the mulch is weed free or use hessian mulch matts available from commercial revegetation product suppliers.

Mechanical spot planting

Compacted soils reduce porosity for air and water, and make root growth difficult. It may be necessary to loosen compacted soils to allow seedling roots to grow deep and wide enough to access soil moisture and nutrients. Drilling single auger holes is a relatively low-disturbance way to loosen compact soils.

Augers will break up hard or compacted layers for better moisture, air and root penetration. Hand augers are most suitable for relatively soft soil, and for small seedlings such as plugs or Hiko cells (Figure 15.4). For most purposes a 100 mm long bit will be sufficient.

Figure 15.4: Mechanical auger. Photo: D. Carr

Tractor-mounted augers can be used for digging tree holes. A depth of 450 mm should be sufficient for most seedlings. Be careful that the auger does not 'polish' the side of the hole as this will restrict root growth. It may be necessary to roughen the sides of the hole with a crowbar. Some augers, such as the CSIRO or Kimseed Tree Auger® (**www.kimseed.com.au**; 08 9446 4377) are designed to roughen the sides of the hole as they work (Figure 15.5).

Figure 15.5: CSIRO (Kimseed) Tree Auger. Photo: D. Carr

As with hand-dug holes, auger holes should be filled with water and allowed to drain away before planting the seedling.

Another method to alleviate compaction without causing major disturbance is to use an Air Spade. Air Spades work in conjunction with an air compressor to release a sudden blast of high-pressure air into the soil 30–45 cm below the surface. See Section 8.1 for more information.

Node planting

In many woodland patches, there will be areas of gaps or disturbances, especially following weed control activities. Using the methods described above, or hand broadcasting of seed (Section 15.3), these gaps can be revegetated to occupy the space and reduce opportunities for weed re-invasion. This new 'node' of vegetation can be a source of seed and further expansion.

High-disturbance planting methods: enlarging or connecting woodland patches

Bigger, rounder woodland patches are more resilient to extreme events and are able to provide more resources and habitat. Revegetation of land adjacent to woodland patches is one way to increase the size of these patches or connect them with other patches. On land previously cropped or on improved pasture (State 4), high-disturbance techniques can begin the revegetation process in a quick and efficient manner as long as there is adequate preparation and follow-up. Be aware that these techniques are not appropriate for States 1, 2 or 3 and so are not permitted within your Environmental Stewardship site.

Planting cycle

Weeds are the biggest cause of revegetation failure. Successful revegetation into weedy disturbed sites depends on preparation and patience.

Follow a four-year planting cycle for maximum success, with two years of preparation before planting and two years of monitoring and maintenance afterwards. Most nurseries require six months' notice to supply trees and shrubs. For difficult-to-propagate species or species not usually grown (such as most ground layer plants), nurseries are likely to require two years' notice. Planting sites also need sufficient time to 'bank' moisture before planting.

After planting, the new seedlings are vulnerable to weeds, browsing and insect pests. They will need to be closely monitored to ensure high survival and good growth. In dry periods supplementary watering may be needed.

Ground preparation

Ground preparation aims to create an environment that allows good root development in the newly transplanted seedling and that makes planting easier and more efficient.

Deep ripping

For trees and shrubs, the best ground preparation is deep ripping unless the soil is sandy. A single-tine ripper will shatter the subsoil and create fissures for water infiltration and root development. Rip to a depth of 40–60 cm when the soil is relatively dry, and at least six months prior to planting so there are no air pockets around the tree roots at the time of planting. To create a more natural appearance to the planting, rip curves rather than straight lines. Rip on the contour of steep slopes and never on soils prone to sub-soil erosion (tunnelling).

If the soil is compacted, but the intention is also to revegetate with ground cover plants, then an implement with multiple ripping tines is more appropriate. Such an implement shatters all of the soil between the tines, so planting does not have to be confined to the rip lines. Grasses and other ground layer plants can therefore be planted across the site with scattered trees and shrubs.

It is not advisable to use deep-ripping implements on cracking clay soils, as the rip-lines will become deep cracks when dry.

Cultivation

Cultivation is a good way to prepare the ground for plantings of grasses and ground layer plants. Cultivating implements are also the most suitable for cracking clay soils. Cultivators, disk-ploughs and rotary-hoes work well on soils that are not compacted, and where a soft surface soil is required for easier planting and root establishment (Figure 15.6). Rotary hoes are best used on small areas, or to cultivate over the top of rip lines. Cultivation must be integrated with comprehensive weed control. Cultivation tools can be used in combination with harrows to create a finer tilth and to smooth the surface. These implements can also be used after deep ripping to provide a softer surface soil for planting.

Mounding

Mounders are typically used in forestry plantations to create a large volume of soft soil for rapid root development and plant growth (Figure 15.7). Most mounders are used in conjunction with deep-rippers (up to 1.2 m) and may be drawn by bulldozers or tractors. Mounders work best on bare soil or where all weeds have been killed and allowed to dry out.

Figure 15.6: a) A tractor-mounted ripper-mounder showing ripping arm and mounding discs. b) Ripped and mounded soil after one pass. Some applications will require two passes. Photos: D. Carr

For woodland restoration, mounding should only be used for tree and shrub establishment where there is a risk of waterlogging or soil salinity. The mounds can lift the new seedlings out of the waterlogged or salty zone until they are strong enough to survive. Mounding is not recommended for sandy soils, areas with mean annual rainfall less than 600 mm or where establishing grass and ground layer plants.

Long fallow

Long fallow uses natural soil processes to prepare a suitable planting environment. It is the best technique for cracking alluvial clay soils (black and grey vertosols). Long fallow builds reserves of soil moisture and creates a soft surface that is easy to plant into. The site must be kept free of weeds for a period of up to two years before planting. In this way, loss of soil moisture due to evapotranspiration from plants is reduced. The self-mulching property of these soils means that evaporation from the soil surface is low, and planting can take place any time when there are a few millimetres of rain to wet the surface. Long fallow can also be used to prepare self-mulching soils for assisted natural regeneration and direct seeding. Long fallow is not appropriate to use on soils with a high risk of erosion from wind or water.

Weed control before and after planting

Weed control for revegetation is critical and involves:

- removing actively growing weeds well before planting to allow the site to build up soil moisture
- controlling weeds as they emerge from the soil seed bank
- controlling weeds that emerge after planting for at least two years.

Typically, for large areas, herbicides are used alone or in combination with cultivation. Alternative methods include nutrient management, scalping, flaming and mulching. An area of at least one metre diameter should be kept weed free around each planting spot for two years before and after planting.

Up to four applications of herbicide may be necessary to ensure a weed-free site at planting time:

1. a full year before planting (two years is better) and in the same season, to kill existing plants and prevent seed set

2. follow-up application in late summer (summer rainfall areas) or autumn (winter rainfall areas)
3. third spray applied six to ten weeks after the second spray to control opportunistic weeds
4. final spray just before planting. If using residual chemicals here, follow the 25:25 rule – wait 25 days after application or wait for 25 mm of rain before planting (or seeding). The final spray may also include other chemical applications, such as insecticide for the control of red-legged earth mite or lucerne flea.

Vigorous perennial grass weeds like phalaris, Coolatai grass, African love grass and Chilean needle grass are likely to need repeated applications of glyphosate to control them. Residual herbicides should not be used with any revegetation methods that rely on soil stores of native seed, as they will kill germinating natives as well.

Herbicides can be used to spray individual planting spots (one to two metres diameter), strips (one to two metres wide) or the entire paddock. Strips of vegetation should be retained if the site slopes more than 10° or if the soil is highly erodible.

Make sure your equipment is appropriate to the size of the job. Backpack sprayers are suitable for spraying small areas or individual weeds, while a spray unit with a tank mounted on a ute or quad bike will be necessary for larger areas. For very large areas, a boom spray will be more efficient.

Always consider other alternatives to herbicides to avoid damaging pre-existing native species. A combination of cultivation and grazing may be more appropriate in many instances, but assess the risks of erosion and soil moisture loss before using these techniques. Weed control strategies that can be used for assisting the survival of planted vegetation are discussed at the end of the chapter .

Nutrient reduction

One way of making the site less favourable for weeds is to lower the levels of nutrients. On former cropping land (State 4), nutrients can be 'mined' by growing unfertilised crops that are then harvested and removed from the site. Successive crops will have reduced yields, but will also run down the levels of soil nutrients. As planting time nears, newly emerging weeds can be controlled and will be much less vigorous under lower nutrient levels.

Suitable crops include wheat, barley, canola or pumpkins. Avoid using species likely to become weeds in revegetation such as oats or pasture grasses. Legumes should not be used because they will increase soil nitrogen. Chapter 11 covers the following methods relating to nutrient reduction for revegetation:

- nutrient mining in higher quality remnants
- No Kill Cropping
- nutrient mining in former pasture sites.

Scalping

Scalping is an effective technique to control weeds and prepare a site for restoration of the ground layer vegetation (Box 15.4). Scalping for seedling planting and direct seeding follows the same principles and procedures as for assisted natural regeneration, which were detailed in Chapter 14.

To prepare a site for seedlings or direct seeding, the whole site or individual rows can be scalped, depending on the revegetation design, the erosion potential of the soil and the slope of the site. Scalping specifically for nutrient management is covered in Chapter 11.

Table 15.1.
Planting seasons for regions where box gum grassy woodlands occur. Dark green = preferred planting time; light green = seasons where planting is possible, but slightly riskier.

Region	J	F	M	A	M	J	J	A	S	O	N	D
Northern Victoria-Southern NSW												
NSW Central West												
Northern NSW												
Southern Queensland												

When to plant

Table 15.1 gives an overview of the best time to plant by region. In winter rainfall areas, planting should wait for the 'autumn break' – the onset of rains after the dry summer period. If you plant in winter, be careful with frost-sensitive species or when planting in frost hollows. Use tree guards or dip seedlings in anti-transpirants such as Envy® (**www.agrobest.com.au**; 07 5596 0622) prior to planting for added frost protection, or delay planting these species until spring.

Planting large areas

For large plantings, where the soil surface is soft and weed free, **planting tubes** (e.g. Potti Putki) can be used (Figure 15.7). These tools enable a skilled planter to plant seedlings without bending. Most planters can use a planting tube at walking pace and easily plant 1000 seedlings in a day.

Mechanical planters are sometimes used for very large revegetation projects. Consider using mechanical planters if you have one available (for example through your local Landcare network or CMA) and if you intend to plant more than 10 000 seedlings on flat or undulating country. A well-prepared site is required to allow a mechanical planter to operate efficiently.

Figure 15.7: A Potti-Putki tree planter. Inset: planter with beak open. Photos: D. Carr

15.3 Direct seeding

Direct seeding is a technique that sows seed directly into the place where it will grow. Direct seeding is cheaper and quicker than seedling transplants, but is less reliable. Native seedlings do not usually all emerge in the first season after sowing and some may emerge up to three years after sowing in response to the most favourable environmental conditions. Like seedling planting, success with direct seeding depends on good site preparation and weed control.

Seed preparation

Some seeds will require some form of treatment before seeding to increase the chances of germination. For example, hard-seeded species such as Acacia and other peas should be scarified or placed in boiling water then soaked overnight. Some species benefit from soaking in smokewater overnight before sowing. Other species may need to have awns, wings or appendages removed in order to travel through the seeder. The book *Growing Australian native plants from seed* by Murray Ralph is one of the best sources of pre-germination treatments. See Appendix E for more information. The Australian Native Plants Society also has an informative website on seed preparation (**www.asgap.org.au/seed.html**). Local experts can also provide advice.

The species that usually work best in direct seeding include wattles, peas, some eucalypts, casuarinas, grasses, daisies and 'pioneer' species (the first to come up after a disturbance in natural woodlands). Create a mix of species for your seeding objectives. Separate seed to suit the seeding equipment. For seeders capable of sowing at two depths, separate seed into buried and surface-sown species. As a general rule for wattle-rich seed mixes, use about 400 grams of viable seed per kilometre of sowing line in dry areas (400–600 mm rainfall) and 300 g/km for areas with rainfall more than 600 mm.

Seed may be vulnerable to predation by birds or removal by ants after sowing. Magnesium carbonate or other deterrents are regularly used to discourage ants. Red-legged earth mites, lucerne fleas and even snails often prey upon newly emerged seedlings. If mites are a known problem, implement a control program in advance. Ask your local Department of Primary Industries (or equivalent) agronomist for advice. If rabbits or wallabies are a problem, a pre-planting control program and fencing will be needed.

'LAY AND SPRAY' (BOX 15.3)

The 'lay and spray method' is a technique that has been used to successfully establish kangaroo grass in small areas[99]. Lay and spray is conducted as follows:

- When the seeds are ripe (usually in January), harvest kangaroo grass either by hand or with specialised native grass harvester (ref).
- Immediately after harvest, spread the kangaroo grass hay onto the site. After the seeds drop, rainfall helps the seed awns screw into the soil.
- Apply herbicide to the site in winter, after the tall perennial weeds have grown through.
- Burn the kangaroo grass hay at the earliest opportunity in spring; kangaroo grass will begin to germinate in November.

Low-disturbance direct seeding methods

Brush mulching

The simplest method of direct seeding is brush mulching. Branches, stems or fruit clusters containing ripe seed are cut from existing plants and laid onto bare sites where the seeds can fall from the fruit and grow (for example, see Box 15.3). Brush mulching is commonly used with kangaroo grass, woody shrubs such as *Acacia, Leptospermum* and *Callistemon*, eucalypts and daisies such as *Xerochrysum* and *Ammobium*. The cut branches or stems provide emerging seedlings some shelter and protection from browsing.

The best sites for brush mulching are weed-free patches of bare soil. Prepare the soil by roughening the surface with a rake or rake hoe. Lay the branches across the soil with

little overlap. Material for brush mulching can be sourced from within the woodland patch or from nearby vegetation. For shrubs, take less than 10 per cent of the foliage from any individual. For grasses and forbs, only harvest in patches, leaving at least 50 per cent of the fruiting plants intact.

Niche seeding

Niche seeding involves sowing seeds into small niches prepared with hand tools. It requires minimal disturbance and can take advantage of natural gaps between plants in high quality woodlands. It is quick and effective. A rake-hoe is the most useful tool for niche seeding. The flat blade of the hoe chips out any weeds and roughens the surface, while the rake side is used to create a level, furrowed surface (Figure 15.8). Seeds are sprinkled onto the prepared niche by hand, or using a hand-made shaker. Seeds are pressed firmly into the soil with the flat of the rake-hoe head. The seeded niche can then be watered and marked with a bamboo stake for later monitoring.

Figure 15.8: Using a rake-hoe to prepare a niche seeding site. Photo: D. Carr

A plug-planting tool can also be used to extract a shallow (one to two centimetres deep) hole from the soil. Seed is sprinkled into this hole and then firmed into the soil with fingers or a piece of wood. There are also specialised tools available that create a small niche and then drop a set amount of seed down a tube into the soil (Figure 15.9).

Figure 15.9: This niche seeder moves away a small amount of soil then drops a specified amount of seed from the bottle on the tube. Photo: D. Carr

Hand broadcasting

Seed can also be hand-broadcast onto a good quality site, particularly where there are few weeds and plenty of gaps between tussock grasses. This method is a good way to re-introduce species that are missing from a woodland (e.g. State 2). Heavier seeds such as those of *Acacia* can be broadcast as though 'feeding the chooks'. Lighter seed should be mixed with a bulking agent such as coarse sand, sawdust or layer mash. The bulking agent should be about the same size as the seed for maximum success. Light weight, fluffy seeds such as those of daises and some grasses can be gently floated onto the site, using the wind (their natural dispersal agent) to spread them.

Seed can be coated to provide some protection from predation and drying-out. Seed coatings, such as clay and water slurries or commercial egg white-based products, increase the size and weight of the seeds, making them easier to disperse in the field. Some seed supply companies provide pelleted seed, which adds weight and often includes a wetting agent or pesticide (e.g. for ants or red-legged earth mite; Figure 15.10).

Clay balls can be created by rolling seeds in damp clay up to one centimetre diameter and then drying them. After the balls are tossed around the site, they will gradually dissolve to release the seed in damp conditions. This technique works well with scarce, medium size seeds such as those of lilies, *Goodenia, Pelargonium* and sedges.

Figure 15.10: *Poa* seed pelleted with a wetting agent for hand broadcasting

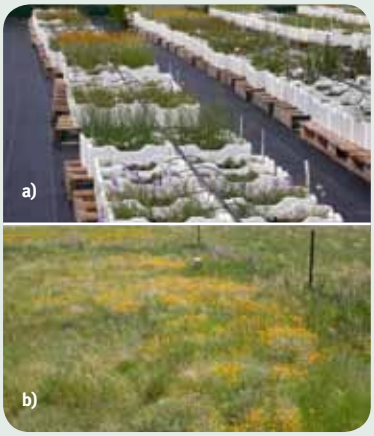
Node seeding

This is a technique for establishing species-rich patches within existing pastures with low diversity (State 3) or in revegetation sites (State 5). This method works well where there are only small quantities of seed of a number of species. Nodes up to 10 m x 10 m in area are cultivated by hand or with a rotary hoe. Weed control is carried out using one of the methods described earlier. Seeds are sown when the soil is moist; the surface is then lightly raked over. Seedlings can also be established in these nodes. Nodes should be fenced from livestock, kangaroos or rabbits as necessary. Nodes can provide a continuous source of seed for gradual dispersal into surrounding areas.

SCALPING AND TURF SEEDING: THE 'GRASSY GROUNDCOVER' METHOD (STATE 3 AND 4) (BOX 15.4)

In Victoria, a partnership between Greening Australia and the University of Melbourne has developed an innovative and successful technique for establishing complex grasslands from bare paddocks. The 'Grassy Groundcover' project was set up to revegetate locally rare native grasslands on the Volcanic Plains of Victoria. The project solved the seed supply problem by collecting small samples of seed of a wide range of species and growing them in foam boxes, for later seed harvest. This technique enabled the project to substantially increase the amount of seed available for restoration works.

To solve the weed control problem, sites were scalped sites to remove weed seeds and the nutrients that favour weeds over natives (Figure 14.1). After scalping, a mixture of native species was sown from a single seed box using a modified turf seeder. The technique is slow, and takes many years to produce enough seed to sow more than a hectare, but the results have been outstanding. This is currently the only technique that exists to restore successfully grasslands or grassland groundcover species in woodland [100].



Figures: a) Foam box seed production system, Dooen, Victoria, b) A mix of native grasses and forbs at a site sown in Colac, Victoria in 2005. Photos: P. Gibson Roy

High-disturbance direct seeding methods

As with seedling planting, high-disturbance direct seeding should only be used outside existing woodland patches to increase their size or to connect them to other patches. These methods should not be used in State 1 or 2 woodlands and only used sparingly (such as in strips) in State 3 woodlands.

Mouldboard ploughing

Mouldboard ploughing creates a mixture of furrows and ridges to catch and hold seed and moisture. This method works best in areas of high rainfall (more than 700 mm per year). The site should be rolled, either with a light roller or with the wheels of a tractor, to close the large air gaps created by the plough. The whole paddock can be prepared in this way or in strips. Seed is then hand broadcast as described earlier. A seed spinner can be used for maximum dispersal of seed.

Figure 15.12: Germinator grass planter. Photo: D. Carr

To prepare sites for mouldboard ploughing, use heavy grazing followed by two applications of knock-down herbicide when weeds are actively growing. The site must be largely weed-free when ploughed.

Mechanical direct seeding

Several purpose-built direct seeding machines are available for sowing seeds of native plants. Most seeders are designed to sow a single row in each pass, although recent advances in direct seeding technology include the modification of commercial sowing machinery for native seed. These adaptations to common farming machinery show great promise and may be available for use in the next few years.

Weed control should be carried out as described for seedling planting prior to using direct seeders. Most seeders will scalp soil out of the sowing zone with a disc or blade, which further reduces weed competition. Seeders can often sow seeds of different sizes at two or three different depths. Some seeders are also able to add gypsum, smokewater, bitumen mulch, sand mulch and soil biota inoculants. Setting up and operating the machine to sow seed at the right depth and spacing for the conditions requires skill and practice. If you have not used a seeding machine before, it is advisable to get some advice or training, or even employ a skilled direct seeding contractor.

One of the most common seeders is the 'Burford Seeder', which uses a disc scalper and press wheel in addition to the seeding boot. The Burford creates minimal disturbance compared to mouldboard ploughing and would be suitable for adding new species to fertilised native pastures (State 3). Other seeders used in the region include the Hamilton Treeseeder, the EcoSeeder and the GreenTech Seeder, although not all of these are currently in production. Contact your local Landcare network, Greening Australia branch, CMA or a professional direct seeding contractor.

Pasture seeders or specialised native grass seeders also exist to establish a range of grass and forb species. These seeders often work with minimal soil disturbance by sowing seed behind a shallow boot or a disc. Seed is usually dropped by gravity from a single seed box or may be forced through a delivery tube by air. 'The Germinator' is a grass planter especially designed to plant native grasses (**www.rosevalewelding.com.au**; Figure 15.11). Other specialised

native grass planters are produced locally throughout the box gum grassy woodlands region. Seek local advice about what direct seeding machinery and expertise are available in your district.

Post-planting weed control

After sowing, weed control may be necessary. Herbicide application needs to be careful and selective. If no grasses have been sown in the mix, grass-selective herbicides can be over-sprayed to remove grass weeds. Shielded sprayers can also be used to spray strips parallel and close to the direct seeded strips. Weeds within the direct seeding rows may need to be hand-pulled or chipped if they are vigorous enough to compete with emerging seedlings. When weeds are taller than emerging plants, a rope-wick applicator can be used to wipe herbicide onto the weed foliage. Weeds should be controlled for at least one, and preferably, two years after sowing.

Illustration by Newnham.

Chapter 16. Creating and improving buffers

Remnant vegetation is susceptible to damaging effects of surrounding activities. There are methods for managing these edge effects, as well as creating buffers to improve conservation (and often production) goals on properties with remnant vegetation. In many cases, managing edge effects and creating buffers perform multiple functions.

The key objective is to 'soften' the edge of a woodland to reduce the amount of wind, nutrients, salt, weeds and harsh sunlight coming in from cleared paddocks. Dense vegetation in wide plantings will be more effective at capturing these contaminants than sparse vegetation.

Often, edge-softening activities help to mitigate several edge effects at once. Examples of edge-softening activities include:

- replanting woodland vegetation around the edges of remnants
- creating adjacent belts of shrubs like saltbush or woodlots for timber and firewood
- moving to less intensive land uses next to remnants; shifting from annual crops to perennial pastures will reduce fertilisers, pesticides and herbicide drift into a woodland patch (for example, lightly grazed native pasture can be located between remnant woodland and the sown pasture to help prevent spread of exotics and accumulation of nutrients into the woodland)
- integrating widely spaced alleys of trees or cluster plantings into paddocks adjacent to woodlands (Box 16.1).

CREATING AND IMPROVING BUFFERS EMPLOYS THE FOLLOWING PRINCIPLES:

10. **Minimise edge effects**; for example, create a buffer or lower inputs in adjacent paddocks
11. **Keep the nutrient and water cycles across your whole property in mind**
12. **Use only locally indigenous or locally adapted species for plantings**

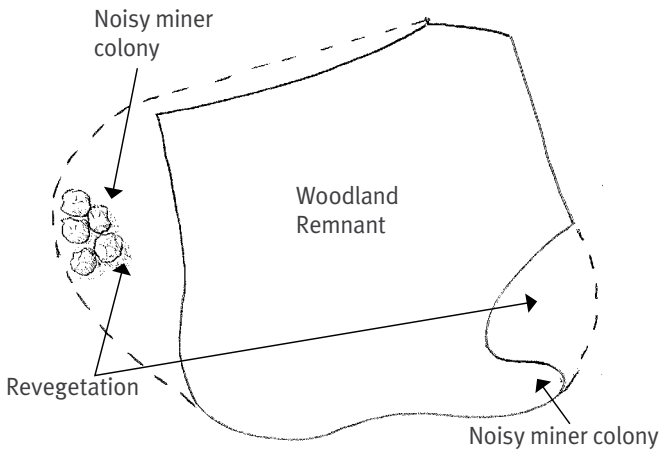


Figure 16.1: This diagram shows where noisy miners are likely to have colonies, and where revegetation works can help reduce their competitiveness. Some areas of revegetation may require new fencing to restrict livestock.

WHOLE OF PADDOCK REHABILITATION (WOPR) (BOX 16.1)

WOPR is an exciting, innovative program by Greening Australia that aims to rehabilitate entire paddocks using a mixture of stock exclusion, direct seeding and rotational grazing. The program targets 'tired' paddocks: those that are likely to have few remaining trees, sparse ground cover and perhaps other issues such as erosion or salinity.

Land managers who participate in the WOPR program enrol an entire paddock – at least 10 ha but preferably 20-40 ha for 5-10 years. This includes a 5-year period of revegetation and stock exclusion, and rotational grazing for the remaining 5 years. Payments help offset production losses in the first 5 years. Enrolling entire paddocks means that fencing costs are negligible.

Depending on the condition and location of the paddock, native trees and shrubs will be direct seeded either in widely-spaced alleys along the contours, or as clusters or clumps of vegetation. The program covers the full cost of direct seeding.

The WOPR program reports both conservation and production benefits, including:

- improved health and survival of stock
- additional feed (browse) for stock
- return of productive pasture to eroded or saline areas
- improved native pasture
- improved soil health and stability
- carbon sequestration
- regeneration of native vegetation and seed source for future revegetation
- habitat for wildlife
- buffering of remnant native vegetation
- 'stepping stones' of vegetation to improve landscape connectivity

For more information on WOPR, please ring Greening Australia Capital Region on (02) 6253-3035

Photo: Greening Australia

Small remnants that are less than 10 ha will benefit most from edge plantings of native trees and shrubs. The added structural complexity creates shade, slows wind and provides habitat for wildlife like birds that struggle to find sufficient resources in small patches.

Noisy miners

If noisy miners are prevalent in your woodland or small patches of trees near woodlands, they may be excluding many of the smaller woodland-associated birds that are important for woodland health. These miners thrive in partially cleared woodlands with lots of edge, especially in the corners and peninsulas of remnants (see Chapter 4). Improve the habitat for smaller woodland birds and discourage noisy miners in the following ways:

- Plant or seed structurally diverse vegetation in a way that creates more interior and less edge (Figure 16.1).
- Add shrubs and encourage natural regeneration of the understorey. Use shrub species that serve as refuge and as food resources for smaller birds.

When revegetating or augmenting small clumps of trees in paddocks, use the same principles as for augmenting or revegetating larger remnants.

Chapter 17. Retaining or adding habitat

The plants associated with box gum grassy woodlands are important in their own right, but what would a woodland be without any animals? This chapter looks at three ways to retain or add habitat features in box gum grassy woodlands, particularly those in States 2 and 3.

17.1 Standing live and dead timber

Hollows are found in older, fallen and standing trees and are used by over three hundred species of Australian vertebrates, including birds, bats, reptiles and mammals [101]. A variety of all hollow-bearing structures increases biodiversity. These trees are critical hard-to-replace biodiversity assets (Figure 17.1). Take extra care of these, including protecting them when using fire or heavy machinery.

Figure 17.1: This mature Blakely's red gum contains several hollows including the large one in the upper left of the image.

Fallen timber

Right across the box gum grassy woodlands range, fallen timber has been removed for firewood, cleared for cropping or simply tidied up. Fallen timber might look messy, but it is likely to be someone's home. Wildlife, from birds to the beetles they feed upon, have been greatly disadvantaged. For box gum grassy woodlands, the amount of fallen timber that should be present is highly variable [102], but expect more from stands of ageing trees than from younger stands (Figure 17.2). Yellow box woodlands tend to have more fallen timber than white box, with grey box somewhere in between. At least four to ten cubic metres per hectare are desirable. Measuring the amount of fallen timber is complicated; the easy way is to look for 'messiness' (Box 17.1).

In most patches that have not been tidied up or used for firewood collection, fallen timber is likely to be adequate. But in woodlands where fallen timber has been removed, recovery can take decades as trees shed branches or fall. In derived native grasslands, timber will never accumulate unless it is added or trees are planted. If fallen timber is scarce then consider adding timber to the woodland or derived grassland.

RETAINING OR ADDING HABITAT EMPLOYS THE FOLLOWING PRINCIPLES:

2. **Manage for patchiness**
4. **Use the Precautionary Principle in your management**
5. **When trying new approaches, test a small patch first**
6. **Restore the basics before attempting to restore the details**
8. **Maintain ground cover**

Figure 17.2: Coarse woody debris in white box woodland near Albury, NSW.

THE HAPPY WANDERER'S METHOD OF CALCULATING COARSE WOODY DEBRIS (BOX 17.1)

Next time you take a walk through your woodland, pay attention to how much fallen timber there is. Then ask yourself the following questions:

- Can you see an assortment of logs and branches of different sizes and stages of decay from any given point?
- Is the fallen timber in the woodland 'randomly' scattered, rather than piled up?
- Are you reasonably certain that neither you nor the previous owner has collected wood of any size or quantity from the woodland?

If you answered yes to at least two of these questions, then it is likely you do not need to add any timber to your woodland.

Figure: Measuring coarse woody debris. Photo: Greening Australia

Adding coarse woody debris

Adding dead timber to a patch may not be easy, but wildlife will thank you for it.

Where to get it

- Some timber can come from thinning operations if you have surplus tree regeneration. But don't thin just to obtain timber, only thin if necessary and distribute some of the thinned wood elsewhere. For more on ecological thinning, see Chapter 14.
- If timber has been piled up from previous 'tidying up', consider redistributing it. Make sure the timber is weed free. This is a good way to reduce rabbit harbour, as they prefer piles to individual logs and branches.
- Your local shire council may have dead wood from removal of trees and branches on roads, but see the list of dos and don'ts below.

Where to put it

Where you add coarse woody debris will probably be constrained by access and machinery. Fortunately, timber can be habitat anywhere, including in derived native grasslands. A 'random' pattern of fallen timber is ideal, but some other ideas for arranging timber are:

- Place timber perpendicular to the flow of water, sediments and nutrients to capture resources on site.
- Consider timber to be refuge islands and place it near the middle of large gaps.
- Treat timber addition as an experiment in one defined area and then monitor its effects.

Figure 17.3: A forestry forwarder drops logs into Goorooyarroo Nature Reserve. Photo: A. Manning

DOS AND DON'TS OF ADDING TIMBER

DO:

- ✓ Ensure the timber is weed and seed free
- ✓ Ensure no other habitat is being destroyed
- ✓ Maintain proper hygiene on equipment that is used
- ✓ Mix sizes and types of logs where possible
- ✓ Remove any seed-bearing parts of the timber if sourced elsewhere
- ✓ Consider potential conflicts with other management such as burning to stimulate regeneration, direct seeding or slashing
- ✓ Add timber when the soil is dry and erosion risk is low

DON'T:

- ✗ Risk introducing weeds or other exotics with timber
- ✗ Use heavy machinery in high quality patches or when the ground is wet
- ✗ Create piles of logs – this encourages rabbits
- ✗ Drag timber or cause other soil disturbance
- ✗ Use non-native or non-local species

How to do it

Researchers from the Australian National University added 2000 tonnes of coarse woody debris to Goorooyarroo Nature Reserve in the ACT as a restoration experiment (Fig 17.3). You don't need 2000 tonnes and a forwarder, but you do need to have an idea of where you want to add timber before you haul it to the patch. Smaller stems can be 'flung' from the back of the ute. Larger stems and logs can be rolled off the side with a crowbar or with the help of another person.

17.2 Bush rock

Surface rocks are an important part of the structural, ecological and habitat components of native vegetation. They provide shelter from weather, fire and predators, and important places for reptiles to bask and lay eggs. Some rare and threatened plants are only found growing between rocks. Bush rock also inhibits soil erosion and helps maintain soil moisture.

Bush rock is any natural surface rock found in areas of native vegetation. It can be in the form of loose rock or as part of larger outcrops. Bush rock is often removed, as it is a popular feature for landscaping and gardening, and an unpopular feature in a cropping paddock. The means of removal varies from hand picking through to excavation and blasting.

Bush rock removal can also result in physical environmental damage, such as:

- soil and vegetation compaction from vehicles and machinery
- soil disturbance from vehicles and at removal sites, leading to increased erosion and runoff
- loss of plants, seed and germination
- introduction of weeds from vehicles and machinery.

The removal of bush rock has been listed as a 'key threatening process' in endangered ecological communities and some species by the *Threatened Species Conservation Act 1995*.

Can I add bush rock to my woodland?

Adding bush rock is problematic for many of the same reasons as adding fallen timber. There is a risk of weed spread, plus the obvious concern of habitat destruction and soil disturbance when sourcing the rock.

For better or for worse, removing bush rock from paddocks when it constitutes a necessary part of the carrying out of routine agricultural activity is not considered a threatening process under the *Threatened Species Conservation Act 1995*. So there may be some scope for 'relocating' bush rock under this provision, however extreme care must be taken for the reasons mentioned above.

Figure 17.4: 'The value of bush rock': This common blue tongue was found basking on some bush rock while the author and a farmer were looking for an endangered plant that was thought to be growing near the rocks.

17.3 Nest boxes

There is some controversy over whether nest boxes provide a viable means of easing the present and coming shortage of natural tree hollows. As discussed in Chapter 13, trees are not regenerating often enough to replace themselves in the long term. Some models predict that over the next 50 to 100 years, temperate agricultural Australia stands to lose about half of its trees [13,41]. Stands of recent regeneration are good and critically needed, but it may be more than 100 years before hollows form.

This likely shortage of natural tree hollows across most of south eastern Australia will have dire consequences for the many animals dependent on them, including species currently common like grey fantails, laughing kookaburras, eastern rosellas and brush tail possums [103]. The time to get trees growing – whether through natural regeneration or by planting them – is now .

Do nest boxes work?

Although studies show that wildlife such as birds, possums, gliders and bats *do* use nest boxes, they cannot take the place of natural tree hollows. Hollows are more than just holes in trees [101]. They are part of a mature plant community that provides resources such as fallen timber, feeding substrates and structural diversity that new vegetation simply can't provide. Nest boxes aren't enough if feeding and dispersal requirements of wildlife are not also met. Existing living and dead trees need to be protected and new trees planted or regenerated (Box 17.2).

Still, nest boxes are worth a try. Nest boxes can be an interesting way to find out what species are around. Keep in mind that nest boxes will only last about ten years. The tree hollow shortage will last much longer.

Where should I put them?

Nest box location depends on the needs of the animal you are trying to attract. For example, microbats tend to be edge specialists, roosting in cracks in trees and hunting for insects in more open areas. Superb parrots are scattered tree specialists, whereas pardalotes require structural diversity, a more mature canopy and denser trees. Here are some guidelines for nest box placement:

- **In areas of no recruitment or only few young seedlings**. Nest boxes on older trees can help to ease the bottleneck in hollow availability.

ADDING SCATTERED TREES TO THE LANDSCAPE: GETTING CREATIVE (BOX 17.2)

Two farmers wanted to put scattered trees back into their derived native grasslands. They both recognised the ecological and cultural values of the scattered trees, and they wanted to help stop the decline of scattered trees in the landscape. But neither of them wanted simply to plant rows of trees. They wanted something more natural — more random.

These two farmers know each other well. They share stories and discuss farm management. Yet their different personalities led them to two very different approaches to returning scattered trees to their paddocks. Both ways were creative and effective.

Farmer One: leaving a legacy

The first farmer was convinced that his own biases about where a tree 'ought to be planted' would result in an un-natural appearance. To solve this, he enlisted the help of a class of geography students. After a lunchtime sausage sizzle and a short presentation on the value of paddock trees, the kids scattered themselves across the paddock in small groups. Support vehicles brought tree guards, stakes, seedlings and flagging tape to the groups as they moved across the big paddock. Each group planted several 'clumps' of three to four widely spaces trees, and after less than two hours, more than one hundred trees were in the ground. The kids were encouraged to imagine 'their' trees in a hundred years, and invited to visit whenever they liked to check their progress.

Farmer Two: using technology to mimic nature

The second farmer also felt that he would not be able to achieve a natural look, if it was up to him to decide where to plant seedlings. Instead, he used an aerial photo of scattered trees that he felt looked nice and natural. Using a map overlay, he traced the pattern of scattered trees. He then placed this overlay on an aerial photo of the paddock he wanted to revegetate, and used a GIS to mark where each tree was to go. Although the 'pattern' of trees was technically the same in both the original and new scattered tree sites, the differences in topography, orientation, tree species and even soil type will create a different look and feel in the planted paddock.

How will you get scattered trees back into the landscape?

- **In areas where old trees are dying and some middle-aged trees need time to mature**. Nest boxes can be placed on trees that are big enough to support them.
- **In planted areas and in dense regeneration**, because tree hollow formation will be delayed despite thinning. Nest boxes can be placed on trees that are big enough to support them.

What do they look like?

Build your own nest boxes or purchase them. If you build them, work with a basic design and change the dimensions to suit the species you hope to attract. Like tree hollows, nest boxes are *not* one size fits all, and some animals, such as gliders, use several nest boxes (called 'den-swapping'). Different animals require different overall and entrance dimensions. Getting the dimensions wrong can create habitat for invasive species including honeybees, European starlings and noisy miners.

An on-line search for 'nest boxes for wildlife' will bring up some good resources, including one from the Blue Mountains Sustainable Living organisation. There is also a book by Alan and Stacey Franks, *Nest boxes for wildlife.* See Appendix E.

If you wish to attract microbats (they provide great insect control) there are instructions at **natsync.com.au/news/how-to-install-a-micro-bat-box**. To purchase a nest box, try **www.nestboxesfornatives.com.au**, or **www.gardenexpress.com.au/native-nest-boxes/**.

Native flax. Photo: M. Frawley

Chapter 18. Looking after endangered plants and animals

Box gum grassy woodland is an endangered ecological community, which is subject to regulations under either the *NSW Parks and Wildlife Act 1974* or the *Vegetation Management Act 1999* (Queensland), and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. At the end of this chapter detailed information is provided on which management activities require a licence in NSW and Queensland.

LOOKING AFTER ENDANGERED SPECIES EMPLOYS THE FOLLOWING PRINCIPLES:

1. **Know your objective, and keep it simple**
3. **Observe before you act, take notes, and adapt what you do — forever**
4. **Use the Precautionary Principle in your management**
6. **Restore the basics before attempting to restore the details**
14. **Seek advice, read widely, and discuss your ideas with other box gum grassy woodland managers**

Note: If you are doing work that may require a licence, first call your CMA or Natural Resource Management (NRM) body to discuss the activity. They can help with any required applications, or may have a blanket license that can cover the work you propose to do.

One of the reasons many species of plants and animals are either threatened or endangered is habitat loss (Box 18.1). This is true for large carnivores down to the smallest of plants and invertebrates. Human activity has reduced suitable habitat to levels that cannot sustain populations of certain plants and animals. With so little box gum grassy woodland remaining, it should be no surprise that many species associated with box gum grassy woodlands are either endangered or vulnerable. Many of the endangered or vulnerable plants are forbs that occupy the spaces between native tussocks. When exotic plants or overgrown natives compete with the native forbs for light, space, water and nutrients, these forbs often lose out.

HABITAT FOR WHOM? (BOX 18.1)

Habitat is the suite of environmental conditions that allows a particular species to survive and reproduce. The terms 'native vegetation' and 'habitat' are not truly interchangeable. 'Native vegetation' does not recognise the species-specific nature of 'habitat'. Every woodland patch is a bit different and provides homes (habitat) for a unique combination of species.

Similarly, removal of exotic species on your property can also result in 'habitat loss'. For example, thorny shrubs form part of the habitat requirements for a number of small native birds. Ideally, natives such as sweet bursaria or kangaroo thorn would fill this role, but when these are absent blackberry, hawthorn or briar rose do the job. Before you remove these problem plants, consider the habitat they may be providing. Killing but not removing the plant while a native substitute grows may be one way to replace this habitat.

What can I do?

A good place to start is to know what is in your woodland. The aim is to create and maintain the right conditions for threatened plants and animals to grow and survive. Again, the right conditions are different for every species.

If you have a threatened species on your property, aim to maintain and improve its habitat. If you do not have a particular threatened species, do not expect it to show

up just because you have created suitable habitat for it. This principle is especially true for the less mobile species such as plants and many small animals. For example, the golden sun moth is highly dependent on wallaby grasses. The female spends its entire adult life in or near a patch of wallaby grass, 'waiting' for a male mate. Similarly, it appears that golden sun moth larvae feed exclusively on wallaby grasses. Because the female is a very poor flier, and because the male will not fly over more than 100–200 metres of inhospitable vegetation looking for a mate, even the best patch of wallaby grass is unlikely to sprout golden sun moths! But if you do have a population of golden sun moths, make sure you maintain or even expand its habitat — healthy tussocks of wallaby grasses.

Figure 18.1: Golden sun moth female (top) and male (bottom). Photo top: L. Berzins. Photo bottom: J. Robinson.

For more mobile species, the 'If you build it, they will come' principle can apply. For example, the swift parrot breeds in Tasmania in spring and summer, then migrates to the mainland over winter (Figure 18.2). Its food includes the nectar of winter-flowering eucalypts such as white box, mugga ironbark and others, or lerps (residue of sap-sucking bugs) on trees such as grey box. Because swift parrots move and migrate over such large distances, revegetation with winter-flowering eucalypts is likely to attract swift parrots eventually.

Figure 18.2: Swift parrot. Photo: T. Hayashi

There are more than 290 plant and animal species associated with box gum grassy woodlands that are listed as either endangered or vulnerable. Understandably, it is beyond the scope of this handbook to give detailed status and conservation information for more than a handful of them. Here are the species that are showcased in the handbook, and the page on which you'll find more information:

Bush stone-curlew: Chapter 4

Button wrinklewort: Chapter 2

Golden sun moth: this chapter

Murrnong (yam daisy): Chapter 4

Small purple pea: Chapter 9

Swift parrot: this chapter

A list of threatened species associated with grassy woodlands is in Appendix A3. The NSW Department of Environment, Climate Change and Water has comprehensive information on threatened species associated with box gum grassy woodlands. The main website for these resources is

www.threatenedspecies.environment.nsw.gov.au. Some of the resources include:

- threatened species profile search function, on website home page
- threatened species profiles for those listed in this handbook and most of the other 290 plant and animal species. From the main website: → species → find by habitat → grassy woodlands. Click on one of the species to take you to the species profile, which includes preferred habitat, priority actions for recovery, and other information. This list is relevant to Queensland land managers as well, due to high species overlap.

  Some fact sheets on threatened species not included on the main website can be found at: **www.environment.nsw.gov.au/threatenedspecies**. From here, click on Threatened species listing news and publications → Threatened species publications. Scroll down to find Endangered species profiles.

If you require a hard copy of any of this information to be posted to you, contact the NSW Department of Environment, Climate Change and Water on 02 9995 5000.

Regulations

Knowing up front when a licence is required and how to get one can be very helpful.

National

Proposed actions that are likely to have a significant impact on matters of National Environmental Significance (as defined under the *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act))* must be assessed under the EPBC Act and require approval before they can proceed. Those proposals that are not likely to significantly impact on these matters do not require approval under the EPBC Act, but may require approval under state or territory legislation. It is the responsibility of the person undertaking the actions to consider whether a significant impact is likely and, if so, to refer a proposal to the department for consideration under the EPBC Act. There are substantial penalties for failing to refer a proposal that is subsequently found to have had a significant impact on a protected matter.

NSW

Governing legislation: *New South Wales Parks and Wildlife Act 1974*; Section 132C.

Actions that require a licence include:

- adding, sourcing or using threatened plants (vulnerable, endangered and critically endangered)
- collecting voucher specimens for identification purposes, picking cuttings or whole plants, or collecting seed
- harming any protected native plant, or any plant that is a threatened species or is part of an endangered population or an endangered ecological community
- damaging the habitat of a threatened species, an endangered population or an endangered ecological community.

How to get a licence (valid for one year):

Download and fill in the licence application form, available at: **www.environment.nsw.gov.au/wildlifelicences/ScientificResearchLicences.htm**, or by calling the Wildlife Licensing Section at 02 9585 6406 or by writing to Wildlife Licensing and Management Unit, Parks and Wildlife Division, NPWS, PO Box 1967, Hurstville, NSW 1485.

Send your form to the above address. There is no longer a fee required for scientific licence applications. DECC tries to make decisions on applications within four to six weeks of receipt of completed application forms.

Helpful hints on obtaining a licence:

- Get help from your field officer, CMA contact or Landcare coordinator.
- Look at and refer to the Box Gum Woodlands Priority Actions List on the DECC website (see link above).
- If translocating threatened plants, familiarise yourself with the Australian Network for Plant Conservation (ANPC) book, *Guidelines for the translocation of threatened plants in Australia*. See Appendix E for more information.

Queensland

All native plants are protected by the Queensland *Nature Conservation Act 1992*, which regulates the use and harvesting of protected plants for revegetation or conservation purposes. This includes whole plants and parts of plants, such as seeds.

A recreational wildlife harvesting licence is *not* required when harvesting parts of a plant from private property that you own or where you have the owner's permission, provided the plant is not an endangered plant and the parts are for your own personal or recreational use. There are limits to the numbers of cuttings or number/weight of seed you may take. DERM has an information sheet available that lists these limits, available at: **www.epa.qld.gov.au/publications/p00963.html**.

If you are taking whole plants or parts of endangered plants, contact the Ecoaccess Customer Service Unit to find out which licence(s) you may require. All harvesting, whether or not a licence is required, must comply with the code of practice for the taking and use of protected plants. The code is available as a pdf from **www.epa.qld.gov.au/publications/p01955.html**.

The recreational wildlife harvesting licence application form is available from DERM's Ecoaccess website at **www.epa.qld.gov.au/publications/p01205.html**. All of the above documents can be obtained in hard copy by contacting the Ecoaccess Customer Service Unit on 1300 368 326.

Other resources

Threatened species: a landholders guide. This book gives land managers advice on assisting with the survival of 39 threatened species in the Central West of NSW. Includes both plants and animals. Available from the NSW Government bookshop for about $10.

Another similar book is *A landholder's guide to threatened species: tips for saving threatened species in New England* ($16.50). Go to **www.shop.nsw.gov.au**, then browse by subject → Environment, find Threatened Species topic link. By phone: DECC at 1300 361 967.

Wildlife in the home paddock: Nature conservation for Australian farmers, by Roland Breckwoldt (1983). This very popular book can be difficult to find, but may be in your local library. It can also be found on some used book websites such as BibliOz (**www.biblioz.com**) or from Books and Collectables (**www.booksandcollectibles.com.au**).

Tarengo leek orchid (*Prasophyllum petilum*). Illustration: M. Bedingfield

Glossary

Benchmarks are measurements or standards that are expected in woodland of excellent condition; for example, metres of fallen timber, canopy cover of trees, number of non-grass native ground cover species.

Biodiversity is the variety of life. It ranges from genetic diversity to ecosystem diversity. Covering more than native flora and fauna, biodiversity includes breeds of cattle and varieties of wheat. It includes the bacteria, bugs and fungi in the soil. It also includes box gum grassy woodland and all the species of plants and animals it comprises.

Biomass is the mass of living or recently living material within an organism or an ecosystem; for example, the kilograms within a single plant or an entire forest.

Conceptual model is a simplified way of understanding and representing a complex idea. The box gum grassy woodlands State and Transition Model is a conceptual model. This model visually represents the ideas of states, transitions, drivers and thresholds, and their relationships.

Derived native grassland was formerly a woodland but its woody canopy and mid-storey species have been cleared, leaving only the ground cover species. Derived native grasslands are considered part of the box gum grassy woodlands target community, because the native ground cover species have high conservation values.

Disturbance is any event that 'removes organisms and opens up space which can be colonised by individuals of the same or different species' [103]. Disturbances that affect and sometimes threaten box gum grassy woodlands include fire, grazing, cultivation, clearing and herbicide use.

Driver is the process or activity that makes something happen in a system. For example, overgrazing is the driver of the transition from warm season perennials to cool season perennials and eventually to exotic annuals. Land use change, fire, drought and fertiliser are other drivers.

Ecosystem is a complete unit in the environment, including both living and non-living elements working together. Like biodiversity, ecosystems include people. An ecosystem can be as small as a pond or as large as a significant portion of a continent. A farm is an ecosystem that is managed by people. Ecosystems that have not been greatly disturbed or manipulated by human activity can be self-perpetuating.

Ecosystem function refers to how the ecosystem works; that is, which elements contribute to the health of the ecosystem and how these elements relate to each other. For example, the way water and nutrients flow through the ecosystem is often dependent on the amount and types of vegetation (particularly perennial grasses) that provide long-lived protection from erosion. An ecosystem that is functioning well provides services to people and the environment. Some of these services include provision of habitat, climate modification, atmospheric gas cycling and energy flow.

Edge effect is an environmental stress found at the boundary between cleared land and remnant vegetation. Where clearing has been complete and has left little to none of the original vegetation structure, the edge is considered to be 'hard'. Edge effects include increased wind, solar radiation and influx of nutrients from cultivated paddocks.

Functional diversity is the number of different ecosystem processes that are being performed by a particular group of species, such as birds or perennial plants. Functional diversity can also be the number of ecosystem processes operating at a site or in an ecosystem. See also 'Ecosystem function'.

Groundcover is the layer of vegetation that is closest to the ground and covers bare soil, for example grasses, forbs and some very low shrubs. Groundcover also includes leaf litter and other dead vegetation.

Herbaceous describes plants that are not woody; examples include grasses, lilies, orchids and some daisies.

Invertebrates are technically any animals that do not have a backbone. For this handbook, we mean small creatures such as beetles, bugs, bees, ants, butterflies and

worms that are associated with box gum grassy woodlands. Bacteria and fungi are not invertebrates.

Litter is the term for dead plant material that accumulates on the ground. It can come from grasses, forbs, shrubs and trees. It provides habitat for many small species and protects the soil from erosion.

Matrix is the dominant land use in an area. For example, where a patch of box gum grassy woodlands occur, the matrix is typically surrounding land such as improved pasture and cropping land. Some native species can use the matrix as habitat, but others can't. For example, farmland birds like magpies and galahs can use and travel between remnant woodlands and scattered trees, making the matrix fairly hospitable or even imperceptible to them. For less mobile plants or animals, adjacent land use or distance between patches of suitable habitat may make the matrix very inhospitable.

Mid-storey is the layer of vegetation under the canopy or overstorey (see 'Overstorey'), but over the groundcover (see 'Groundcover'). The mid-storey is usually made up of larger shrubs and younger trees, and forms an important structural and habit component of grassy woodlands.

Northern and southern regions. Box gum grassy woodlands occur in areas that can be roughly divided into two predominant climate types: summer dominant rainfall zones and temperate, non-seasonal rainfall zones. In this handbook, we refer to the summer dominant rainfall zone as the 'northern region', and the temperate zones as the 'southern region'.

Nutrient cycling refers to the flow of nutrients such as carbon, phosphorus, nitrogen and water within an ecosystem, and how they are made available and consumed. 'Cycling' indicates that nutrients in a healthy system are retained within that system. Unhealthy ecosystems can lose nutrients to processes such as leaching, runoff or erosion.

Overstorey is the layer of vegetation that forms the canopy. Overstorey and mid-storey can comprise similar species; the key difference is the height of the species relative to other layers. See also 'Mid-storey'.

Precautionary principle is the 'better safe than sorry' rule. The precautionary principle should apply when science lags behind. If, at the time of planning an action, we lack the knowledge to prove that that action will not cause harm, then we should err on the side of caution when making our decision.

Regeneration is the on-site growth of native plants from a parent plant.

Regime is a set of environmental or management conditions imposed on a woodland at a particular time, such as a grazing regime or a fire regime.

Resilience is the ability of something (or someone) to 'bounce back' from a disturbance or hard times. Resilience also refers to the ability of a system to retain function after a shock. A resilient woodland will be able to withstand shocks such as grazing, flood, fire and drought because of its diversity on a number of levels: genetic, species and functional.

Restoration is the use of different activities such as revegetation, soil amelioration, weed and feral animal control, and changing water flows to restore a site to a desired level of functioning and species composition.

Revegetation is active planting or seeding of native plants to add vegetation to a site where it had been removed.

Species diversity is the *number* of species found at a site or in an ecosystem. Species diversity is used interchangeably with 'species richness' in this handbook.

Species composition is the *mix* of species that is found at a site or in an ecosystem, and in defined proportions.

Stoloniferous plants are those that regenerate or form new plants via stolons, which are horizontal shoots at or just below the soil surface, much like runners.

Threshold is a point that, once crossed, causes a fundamental change in how a system behaves. For example, a threshold might be the amount of nitrogen a grassy woodland can tolerate before weeds overtake the natives. A threshold might also be crossed when fire becomes too frequent, resulting in loss of native species, bare ground and an erosion risk.

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Hoary sunray (*Leucochrysum albicans*). Illustration: M. Bedingfield.

Appendices

Brachycome rigidula. Illustration: M. Bedingfield

Appendix A. Native species in box gum grassy woodlands

A1. Indicator understorey species for each woodland state

GENUS/SPECIES (COMMON NAME)	STATE 1	STATE 2	STATE 3	DESCRIPTION AND NOTES
GRASSES				
Themeda australis (Kangaroo Grass)	✓	✓		Refer to pages 10-1 Grassland Flora Guide (Eddy et al.) Most commonly found in eastern parts of BGGW range. Grazing sensitive species. Open areas, can be present but not dominant in State 2.
Cymbopogon refractus (Barbed-wire grass)	✓	✓		Common in northern NSW and southern Qld and often co-dominant with Themeda and other natives. Will tolerate moderate grazing when done in short periods during rotational grazing, but otherwise likely to be sensitive to grazing.
Poa sieberiana (Snow Grass)	✓	✓		Refer to pages 12-3 Grassland Flora Guide (Eddy et al.) Most commonly found in eastern parts of BGGW range. Grazing sensitive species. Located particularly under trees
Bothriocloa macra (Red-leg Grass) *Bothriochloa decipiens* (Pitted bluegrass)	✓	✓	✓	Refer to pages 24-5 Grassland Flora Guide (Eddy et al.) Found across BGGW range, becoming more common with grazing.
Austrodanthonia species (Wallaby Grasses)	✓	✓	✓	Refer to pages 16-7 Grassland Flora Guide (Eddy et al.) There are more than 15 species found across BGGW range, with commonly 3+ species/site- many appear to become more common with grazing.
Dichanthium sericeum (Queensland bluegrass)	✓	✓		Common in northern NSW and southern Qld where it may form a co-dominant part of the groundcover. Tolerant of moderate grazing.
Elymus scaber (Wheat Grass)	✓	✓		Refer to pages 20-1 Grassland Flora Guide (Eddy et al.) Found across BGGW range, tolerates moderate grazing.
Austrostipa Species (Spear Grasses)	✓	✓	✓	Refer to pages 14-5 and 36-7 Grassland Flora Guide (Eddy et al.) 3+ species found across BGGW range, with *A. scabra* becoming more common with grazing.
Aristida vegans (Threeawn Speargrass)	✓	✓	✓	A small wire-grass that tends to become more common with grazing.
Aristida ramosa (Purple Wire Grass)	✓	✓	✓	Refer to pages 34-5 Grassland Flora Guide (Eddy et al.) Found across BGGW range, becoming more common in unfertilized pasture with grazing, due to its lack of palatability. Prefers lighter soils.
Microlaena stipoides (Weeping Grass)	✓	✓	✓	Refer to pages 22-3 Grassland Flora Guide (Eddy et al.) Most common in the eastern, moister parts of the BGGW range. Can tolerate grazing and fertiliser.
Eragrostis species (Love Grasses)	✓	✓	✓	Refer to pages 30-1 Grassland Flora Guide (Eddy et al.) 6+ species found across BGGW range, with *E. brownii* tolerant of moderate grazing.
Enneapogon nigricans (Nineawn Grass)		✓	✓	Refer to pages 32-3 Grassland Flora Guide (Eddy et al.) Found across BGGW range, tolerant of moderate grazing.
Panicum effusum (Hairy Panic)	✓	✓	✓	Refer to pages 28-9 Grassland Flora Guide (Eddy et al.) Found across BGGW range, colonises bare areas and is tolerant of moderate grazing.
Dichelachne species (Plumegrasses)	✓	✓		Refer to pages 26-7 Grassland Flora Guide (Eddy et al.) Found across the eastern part of BGGW range, not tolerant of heavy grazing.
Joycea pallida (Red-anther Wallaby Grass)	✓	✓		Refer to pages 18-9 Grassland Flora Guide (Eddy et al.) Found on shallow, stony soils. Can tolerate moderate grazing due to its low palatability; however is not common in BGGW (owing to ecological preference for poorer soils).
Chloris truncata (Windmill Grass)		✓	✓	Refer to pages 34-5 Grassland Flora Guide (Eddy et al.) Along with other Windmill (umbrella) Grasses more common in western parts of BGGW range, tolerant of moderate grazing.
Sorghum leiocladum (Sarga leioclada) (Wild Sorghum)	✓	✓		

Appendix A1, cont.

GENUS/SPECIES (COMMON NAME)	STATE 1	STATE 2	STATE 3	DESCRIPTION AND NOTES
RUSHES AND SEDGES				
Juncus filicaulis (Pinrush)	✓	✓	✓	Refer to pages 48-9 Grassland Flora Guide (Eddy et al.) Along with other *Juncus* species more common in moist sites in BGGW range.
Luzula densiflora (Woodrush)	✓	✓		Refer to pages 50-1 Grassland Flora Guide (Eddy et al.) Moderately common in moist sites in BGGW range.
Scheonus apogon (Common Bog Sedge)	✓	✓	✓	Refer to pages 52-3 Grassland Flora Guide (Eddy et al.) Common in moist sites in BGGW range.
Carex species (Sedges)	✓	✓	✓	Refer to pages 52-3 Grassland Flora Guide (Eddy et al.) Common along drainage lines and moist sites in BGGW range.
Lomandra filiformis (Wattle Mat-rush)	✓	✓	✓	Refer to pages 54-5 Grassland Flora Guide (Eddy et al.) Common throughout BGGW range.
Lomandra multiflora (Matrush)	✓	✓	✓	Quite common in northern NSW and southern Qld, particularly in rocky sites.
Gahnia aspera (Rough Saw-sedge)	✓	✓	✓	A distinctive 'saw-sedge' common on lighter soils
LILIES AND HERBS				
Dianella longifolia (Smooth Flax Lily)	✓			Refer to pages 56-7 Grassland Flora Guide (Eddy et al.) Most commonly found in western parts of BGGW range. Moderately sensitive to grazing. (Lacey p 228, Tremont p 48)
Dianella revoluta (Black-anthered Flax Lily)	✓	✓		Refer to pages 56-7 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Grazing sensitive species. (Lacey p 24, Tremont p 49)
Thysanotus tuberosus (Common Fringe-lily)	✓			Refer to pages 56-7 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Grazing sensitive species. (Lacey p 212, Tremont p 16-7)
Arthropodium milleflorum (Vanilla Lily)	✓			Refer to pages 58-9 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Grazing sensitive species. (Lacey p 8, Tremont p 48)
Dichopogon fimbriatus (Nodding Chocolate-lily)	✓	✓		Refer to pages 58-9 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Grazing sensitive species. (Lacey p 184, Tremont p 46)
Wurmbea dioica, W. biglandulosa (Early Nancy)	✓	✓		Refer to pages 60-1 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Grazing sensitive species. (Lacey p 46, Tremont p 48-9)
Bulbine bulbosa (Bulbine Lily)	✓	✓		Refer to pages 62-3 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Grazing sensitive species. (Lacey p 80, Tremont p 44-5)
Tricoryne elatior (Yellow Rush Lily)	✓	✓		Refer to pages 62-3 Grassland Flora Guide (Eddy et al.) Common throughout BGGW range. (Lacey p 98, Tremont p 44-5)
Microtis unifolia, M. parviflora (Onion Orchids)	✓	✓		Refer to pages 64-5 Grassland Flora Guide (Eddy et al.) Common in poorly drained sites throughout BGGW range. (Lacey p 152, Tremont p 102-3)
Diuris species (Donkey Orchids)	✓			Refer to pages 68-9 Grassland Flora Guide (Eddy et al.) These orchids prefer relatively undisturbed areas (Tremont p 104-6)
Goodenia pinnatifida (Scrambled Eggs) *G. hederacea* (Ivy-leaf goodenia)	✓	✓		Refer to pages 70-1 Grassland Flora Guide (Eddy et al.) Most commonly found in western parts of BGGW range. Moderately sensitive to grazing. (Lacey p 88, Tremont p 34-5)
Ranunculus lappaceus (Common Buttercup)	✓	✓		Refer to pages 72-3 Grassland Flora Guide (Eddy et al.) Most commonly found in eastern parts of BGGW range. Moderately sensitive to grazing (Tremont p 36-7)
Hypericum gramineum (Small St John's Wort)	✓	✓		Refer to pages 72-3 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing. (Lacey p 120, Tremont p 36-7)
Chrysocephalum apiculatum (Common Everlasting)	✓	✓		Refer to pages 74-5 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing. (Lacey p 118, Tremont p 68-9)

Appendix A1, cont.

GENUS/SPECIES (COMMON NAME)	STATE 1	STATE 2	STATE 3	DESCRIPTION AND NOTES
Leptorhynchos squamatus (Scaly Buttons)	✓	✓		Refer to pages 80-1 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing (Tremont p 68-9).
Triptilodiscus pygmaeus (Austral Sunray)	✓	✓		Refer to pages 80-1 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing. (Lacey p 100)
Bracteantha viscosa (Sticky Everlasting)	✓	✓		Refer to pages 84-5 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing (Tremont p 62).
Podolepis jaceoides (Showy Copper-wire Daisy)	✓			Refer to pages 84-5 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing (Tremont p 56-7).
Microseris lanceolata (Yam Daisy)	✓			Refer to pages 86-7 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Sensitive to grazing. (Lacey p 92, Tremont p 54-5)
Cymbonotus lawsonianus (Austral Bears-ear)	✓	✓	✓	Refer to pages 88-9 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing. (Lacey p 82, Tremont p 54-5)
Cynoglossum suaveolens (Sweet Hound's Tongue)		✓	✓	Refer to pages 90-1 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing (Tremont p 38-9, 42-3).
Pimelea curviflora *P. linifolia* *P.neoanglica* (Riceflowers)	✓	✓		Refer to pages 90-1 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing, but often toxic and so stock tend to avoid them. (Lacey p 104, Tremont p 22-3)
Stackhousia monogyna *S. viminea* (Creamy Candles)	✓	✓		Refer to pages 90-1 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing. (Lacey p 72, Tremont p 42-3)
Asperula conferta (Common Woodruff)	✓	✓		Refer to pages 92-3 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing (Tremont p 24-5).
Drosera peltata (Pale Sundew)	✓	✓	✓	Refer to pages 92-3 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range in poorly drained sites. Moderately sensitive to grazing disturbance (Tremont p 40-1).
Calotis lappulacea (Yellow Burr-daisy) *C. cuneata* (Purple burr-daisy)	✓	✓		Refer to pages 98-9 Grassland Flora Guide (Eddy et al.) More common in the western part of the BGGW range. Moderately sensitive to grazing. (Lacey p 116, Tremont p 56-7)
Vittadinia gracilis (Woolly New Holland Daisy)	✓	✓		Refer to pages 100-1 Grassland Flora Guide (Eddy et al.) More common in the western part of the BGGW range. Moderately sensitive to grazing (Tremont p 58).
Vittadinia cuneata, V. muelleri (Fuzzweed)	✓	✓	✓	Common throughout the northern part of GBBW. V.muelleri appears to be tolerant of grazing. (Lacey p 218, Tremont p 58-9)
Wahlenbergia species (Bluebells)	✓	✓	✓	Refer to pages 102-3 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range where several species may be found at one site. Moderately sensitive to grazing disturbance. (Lacey p 222-4, Tremont p 38-9)
Linum marginale (Native Flax)	✓			Refer to pages 104-5 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range in poorly drained sites. Sensitive to grazing disturbance. Much less common in the northern parts of NSW (Tremont p 38-9)
Ajuga australis (Austral Bugle)	✓	✓		Refer to pages 106-7 Grassland Flora Guide (Eddy et al.) More common in the eastern part of the BGGW range in poorly drained sites. Sensitive to grazing disturbance. (Lacey p 232, Tremont p 76-7)
Brunonia australis (Blue Pincushion)	✓			Refer to pages 108-9 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing. Very scarce in GBBW in northern NSW. Found in southern Qld.
Brunoniella australis (Blue trumpet)	✓	✓		Common in northern NSW and southern Qld. Large blue flowers on short plants are distinctive. Tolerant of light grazing

Appendix A1, cont.

GENUS/SPECIES (COMMON NAME)	STATE 1	STATE 2	STATE 3	DESCRIPTION AND NOTES
Rostellularia adscendens (Pink tongues)	✓	✓		Common in northern NSW and southern Qld.
Swainsona sericea or related spp. (Silky Swainson-pea)	✓	✓		Refer to pages 110-11 Grassland Flora Guide (Eddy et al.) Most commonly found in eastern parts of BGGW range. Grazing sensitive species. (Lacey p 240-2, Tremont p 94-5)
Glycine tabacina *G. clandestina* (Vanilla Glycine)	✓	✓		Refer to pages 112-13 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing. (Lacey p 236, Tremont p 92-3)
Desmodium varians, D. brachypodum (Slender-tick Trefoil)	✓	✓		Refer to pages 112-13 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing. (Lacey p 166, Tremont p 92-3)
Oxalis perennans (Grassland Wood Sorrel)		✓	✓	Refer to pages 116-17 Grassland Flora Guide (Eddy et al.) Common throughout BGGW range (Tremont p 36-7).
Geraniam solanderi, G. potentilloides, G. homeanum (Native Geranium)	✓	✓	✓	Refer to pages 118-19 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range; may be 2 or more species present. Moderate to low sensitivity to grazing. (Lacey p 172, Tremont p 42-3)
Convolvulus erubescens Australian (Bindweed)	✓	✓	✓	Refer to pages 120-21 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing. (Lacey p 164, Tremont p 70-1)
Epilobium billardierianum (Willowherb)	✓	✓	✓	Refer to pages 120-1 Grassland Flora Guide (Eddy et al.) Common throughout BGGW range, especially in moist areas. (Lacey p 198, Tremont p 24-5)
Gonocarpus tetragynus (Common Raspwort)	✓	✓	✓	Refer to pages 124-5 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing.
Halogaris heterophyllus (Native Rosella)	✓	✓	✓	Common in northern NSW, and favours damper sites. Not found in southern Qld.
Rumex brownii (Swamp Dock)	✓	✓	✓	Refer to pages 124-5 Grassland Flora Guide (Eddy et al.) Common throughout BGGW range.
Plantago species (Plantains)	✓	✓		Refer to pages 128-9 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range where it may occur with the much more common introduced Ribwort Plantain. Moderately sensitive to grazing. (Lacey p 130)
Solengyne dominii *S. bellioides* (Smooth Solengyne)	✓	✓	✓	Refer to pages 130-1 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing. (Lacey p 44)
Euchiton gymnocephalus *E. sphaericus* (Creeping Cudweed)	✓	✓	✓	Refer to pages 130-1 Grassland Flora Guide (Eddy et al.) Common throughout BGGW range, especially in moist areas.
Hydrocotyle laxiflora (Stinking Pennywort)	✓	✓		Refer to pages 134-5 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range, often at the base of trees. Moderately sensitive to grazing.
Dichondra repens (Kidneyweed)	✓	✓	✓	Refer to pages 134-5 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing.
Aceana ovina (Sheep's Burr)	✓	✓	✓	Refer to pages 136-7 Grassland Flora Guide (Eddy et al.) Found throughout the BGGW range. Moderately sensitive to grazing.
Cheilanthes sieberi (Rock Fern)	✓	✓	✓	Refer to pages 138-9 Grassland Flora Guide (Eddy et al.) Common throughout BGGW range, especially in rocky areas.

Appendix A2. White box grassy woodland: the usual suspects

***** List derived from [15]. There is a high degree species overlap between white box and box gum grassy woodlands generally.

Except in the extreme north of NSW, the following species are typically present in high-quality white box grassy woodlands:

Kangaroo grass	*Themeda australis*
Snow grass	*Poa sieberiana*
Common everlasting	*Chrysocephalum apiculatum*
Small st john's wort	*Hypericum gramineum*
Native geranium	*Geranium solanderi*
Vanilla glycine	*Glycine clandestina*
Black-anthered flax lily	*Dianella revoluta*
Smooth flax lily	*Dianella longifolia*
Common woodruff	*Asperula conferta*
Scaly buttons	*Leptorhynchos squamatus*
Scrambled eggs	*Goodenia pinnatifida*
Riceflower	*Pimelea curviflora*
Creamy candles	*Stackhousia monogyna*
Rock fern	*Cheilanthes sieberi*
Spear grass	*Stipa scabra*
Bulbine lily	*Bulbine bulbosa*
Wattle mat-rush	*Lomandra filiformis*
Grassland wood sorrel	*Oxalis perrenans*

Wattle mat-rush (*Lomandra filiformis*).
Photo: M. Frawley

Vanilla (twining) glycine (*Glycine clandestina*).
Illustration: M. Bedingfield

Appendix A3. Threatened species associated with box gum grassy woodlands

Sources: *Box Gum Grassy Woodlands Project training manual* and from NSW Department of Environment, Climate Change and Water.

Plants

Austral toadflax (*Thesium australe*)

Button wrinklewort (*Rutidosis leptorrhynchoides*)

Dichanthium setosum

Euroa guinea-flower (*Hibbertia humifusa* spp. *erigens*)

Hoary sunray (*Leucochrysum albicans* var. *tricolor*)

Lobed blue-grass (*Bothriochloa biloba*)

Narrow goodenia (*Goodenia macbarronii*)

Small purple-pea (*Swainsona recta*) and other peas (*Swainsona* spp.)

Tarengo leek orchid (*Prasophyllum petilum*)

Yass daisy (*Ammobium craspedioides*)

Discaria pubescens

Diuris spp.

Pterostylis spp.

Mammals

Spotted-tail quoll (*Dasyurus maculatus maculatus*) southeast mainland population

Squirrel glider (*Petaurus norfolcensis*)

Koala (*Phascolarctos cinereus*)

Yellow-bellied sheathtail-bat (*Saccolaimus flaviventris*)

Invertebrates

Bathurst copper butterfly (*Paralucia spinifera*)

Golden sun moth (*Synemon plana*)

Reptiles

Pink-tailed worm-lizard (*Aprasia parapulchella*)

Striped legless lizard (*Delma impar*)

Pink-tailed legless lizard (*Aprasia parapulchella*)

Pale-headed snake (*Hoplocephalus bitorquatus*)

Rosenberg's goanna (*Varanus rosenbergi*)

Birds

Plains-wanderer (*Pedionomus torquatus*)

Regent honeyeater (*Xanthomyza phrygia*)

Superb parrot (*Polytelis swainsonii*)

Swift parrot (*Lathamus discolor*)

Bush stone-curlew (*Burhinus grallarius*)

Major Mitchell's cockatoo (*Cacatua leadbeateri*)

Brown treecreeper (*Climacteris picumnus victoriae)*

Painted honeyeater (*Grantiella picta*)

Square-tailed kite (*Lophoictinia isura*)

Hooded robin (*Melanodryas cucullata cucullate*)

Black-chinned honeyeater (*Melithreptus gularis gularis*)

Turquoise parrot (*Neophema pulchella*)

Barking owl (*Ninox connivens*)

Grey-crowned babbler (*Pomatostomus temporalis temporalis*)

Speckled warbler (*Pyrrholaemus sagittata*)

Diamond firetail (*Stagonopleura guttata*)

Masked owl (*Tyto novaehollandiae*)

Appendix B. Problems to be addressed and management actions by state

Please refer to Chapter 3 for a description of each state. Some of these actions can cause damage if misapplied. Numbers in brackets refer to the relevant chapter number in this handbook for further information.

State	Problem	Possible management actions
1	No regeneration of plants or indicator species missing	Fence the site and exclude grazing (12) Use fire or smokewater to stimulate germination (15) Control exotic weeds in patch to reduce competition (10, 11, 12) Conduct a soil seed bank experiment and transplant quality recruits (8) Plant seedlings grown from high quality seed (15)
1	Maintain the conservation values	Retain all standing trees (alive and dead) (17) Retain all bush rock (17) Do not apply fertiliser Do not cultivate or disturb the soil Do not remove or stockpile logs and fallen timber Practice good weed control hygiene to minimise weed spread (10) Monitor weeds, ferals and regeneration (7)
1	Poor connectivity to other woodland patches	Increase connectivity using revegetation (15)
1, 2	Patches of perennial grass weeds occurring (e.g. Chilean needle grass, Coolatai grass, Yorkshire fog, phalaris, serrated tussock, sweet vernal grass)	Spot spray or dig out small clumps (10, 15, Appendix C) Crash graze periodically (12) Manage grazing to stimulate native pasture (12) Spring burn (9, 10) Monitor and maintain control (7, 10)
1, 2	Patches of annual grass weeds	Crash graze or burn patches in spring to stop seed set of annual grasses (9, 10, 12) Light grazing in autumn and winter to maintain native grass vigour (12) Apply carbohydrate and sow Themeda (11) Monitor and maintain control (7)

State	Problem	Possible management actions
1, 2	Dense tree or shrub regeneration	Assess whether thinning is necessary Leave if patches are small and plants are native Thin with fire (9) Thin manually (14)
1,2	Low habitat value for wildlife	Add logs or branches (17) Increase the number of vegetation layers in the patch (14, 15) Place nesting boxes for target species (17) Control feral predators
1, 2	Tree damage during fire	Spray tree bases and woody debris during controlled burns (9) Extinguish burning trees, particularly those with hollows (9)
1,2	Grazing and browsing damage to plants	Fence to exclude domestic, feral and native animals as necessary (12) Change grazing regimes (12) Reduce farm populations of ferals Control rabbits
1,2	Soil disturbance from animals	Control pig numbers on farm Rip rabbit warrens (States 2 and 3 only) and reduce numbers Reduce total grazing pressure to maintain groundcover (12)
1,2	Feral predators killing or competing with wildlife	Conduct fox baiting program at landscape scale Remove exotic berry bushes (hawthorn, pyracantha, cotoneaster etc) (10) Trap and destroy feral cats
2	Mistletoe killing trees	Prune mistletoe from significant trees with hollows that are severely infested (10) Address underlying cause of tree stress leading to mistletoe infestation (4)
2,3	Low or no tree cover	Plant/direct seed trees at appropriate rate using minimal disturbance (15) Encourage natural regeneration (14)

State	Problem	Possible management actions
2, 3	Tree dieback from insect pressure, herbicide drift, water stress	Prevent stock camping beneath trees Scalp soil beneath tree canopy to remove nutrients; sow with natives such as red grass or Poa (11, 15) (State 3 only) Fence to prevent bark browsing (12) Increase patch size through revegetation (14, 15) Revegetate with dense shrubs to increase diversity and insectivorous birds Do not fertilise and prevent fertiliser drift Avoid using defoliants near woodlands when windy
3	Exotic annual grasses dominate	Herbicide control of grasses (10) Strategic burning (9) Strategic grazing (12) Nutrient removal by harvesting, scalping or carbohydrate addition (11) Revegetate with native perennial grasses (11, 15) No Kill cropping (11) Dense tree revegetation to shade out weeds, followed by thinning (14, 15)
3	Exotic broadleaf weeds abundant or dominant	Use broadleaf herbicides carefully Hand weed or chip (10) Use bush regeneration principles to manage (10)
4	Few or no native species present	Scalping to remove nutrients (11) Establishment of native grass cover by direct seeding followed by tree and shrub establishment (15) Dense tree revegetation followed by thinning (14, 15)
5	Low species diversity	Revegetate with high diversity patches (15)
5	Trees and shrubs present but dense exotic ground cover	Crash grazing or fire to reduce biomass (12, 9) Cultivation between trees (15) Scalping between trees (15) Sow with kangaroo grass hay after topsoil or biomass removal (11, 15) 'Lay and spray' method (15) Dense tree and shrub revegetation (15)

Appendix C: Weed identification and management of selected species

This supplement can help identify some of the key weed species or types of weeds that threaten box gum grassy woodlands. Control options are described, but we recommend you seek further advice from the many weed management resources that exist online, or speak with your local weed management agency.

Identifying plant parts

Learning to identify weeds requires knowledge of some plant parts, like ligules, awns, sheaths and so on. This short glossary will help you get started.

Auricles: the ear-like structures that exist at the top of the leaf sheath (see below) in some species (Figure C1). Auricles can be reduced to a hairy edge in some species. Auricles are quite delicate and can wither quickly, so look for them on young leaves.

Awn: the long, spiky bit that begins at the end of the seed and sticks out from the seed head. For example, common wheat grass and kangaroo grass have very prominent awns.

Corona: a structure that looks like a crown at the junction of the seed head and the awn. A corona is a key distinguishing feature on Chilean needle grass.

Ligule: a membranous structure or collar that sits at the base of the leaf blade, on the inside (Figure C2). The ligule can be found by tracing a leaf down to where it meets the stalk, and bending the leaf back to this point. Ligules can be a simple membrane collar, a membrane collar with a rim of hairs, or a simple rim of hairs. Ligules are often a distinguishing feature for grasses.

Midrib: the vein that runs up the middle of the length of the leaf blade. The mid rib can be pale and prominent or inconspicuous.

Raceme: one form of grass flower arrangement (Figure C3). Racemes are non-branching stems that hold the small individual grass flowers.

Sheath: the part that wraps around the stem, like a cloak, at the bottom of the leaf blade below the ligule. See the diagram next page for an example with Coolatai grass.

Figure C1: Auricles on *Hordeum vulgare* (barley). Photo: M. Lavin

Figure C2: An example of a hairy-membranous ligule at the base of the leaf blade. Photo: M. Lavin

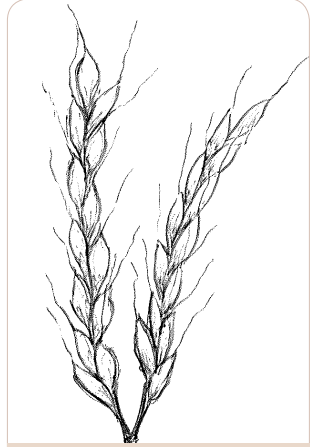

Figure C3: Two racemes of a grass plant.

Exotic perennial grasses

Long-lived weedy grasses pose a serious threat to the understorey of box gum grassy woodlands. Chilean needle grass, Coolatai grass, African lovegrass and serrated tussock are of particular concern. Management approaches for exotic perennial grasses focus on preventing spread and reducing existing infestations.

Prevent spread

- Remove small and isolated infestations before they seed.
- Monitor vulnerable areas such as roadsides and drainage lines.
- Slash into, rather than away from, infested areas.
- Practice vigilant weed control hygiene.

Manage and reduce existing infestations

- Identify and map all infested areas.
- Prioritise areas of high conservation value.
- Plan monitoring and follow-up before beginning treatment.
- Work from isolated patches towards core infestations.
- Work in stages, treating areas small enough to receive thorough treatment and follow-up.
- Follow-up with seeding or planting of natives. Seed-bearing native hay can be used in small areas.
- Use control measures that are tailored for each area and do not damage native species.
- Properly dispose of all slash materials.
- Monitor closely and follow-up as necessary.

Coolatai grass

This grass is an exotic perennial that can invade and dominate native ground cover in box gum grassy woodlands. It was originally introduced as a drought-tolerant pasture grass.

Figure C4: Coolatai grass. Photo: J. Tann

Distinguishing features

Features are dense tussocks to 1.5 m; flowers in a 'V' shape on two hairy white or grey racemes; 5 – 7 awns on each raceme; long, membranous ligule (2 – 4 mm; Figure C4).

Look-alikes:
Kangaroo grass (*Themeda australis*)
Red-leg grass (*Bothriochloa* spp.)
Barbed wire grass (*Cymbopogon refractus*)
and other lemon-scented grasses (*Cymbopogon* spp.)

Kangaroo grass seedlings can look similar to Coolatai grass. The ligule is also membranous, but shorter (about 1 mm). Kangaroo grass flower heads are triangular in shape, rust-coloured and hairless when mature (Figure C5a).

Red-leg grass can also look like Coolatai grass when young, but stems are reddish and flower heads have more than two racemes (Figure C5b).

Barbed wire grass and other lemon-scented grasses also have paired racemes (or sometimes three), but unlike Coolatai grass, the leaves smell like lemon when crushed (Figure C5c).

Basic biology

Main growth is in late spring through summer, responding quickly to rain. The grass spreads easily by seed and does not need cross pollination. Seeds stick easily to clothes, fur, vehicles and tools. Seed growth and maturation is over an extended period. Seeds germinate readily. Regrowth occurs from base after grazing or dormancy. This species spreads with fire.

Control options

1. Physical removal:
   a. Remove entire plants before seeding if possible. If flowers have developed, bag flower heads first, then grub individual plants.
   b. Remove the base of the tussock with a mattock and minimise disturbance to soil.
   c. Dispose of plants safely, monitor and check for regrowth or seedlings.
2. Grazing:
   a. Intensive grazing in early summer keeps the plant in the vegetative and palatable stage.
   b. Avoid creating bare soil to prevent further establishment.
3. Burning:

   Burning will stimulate extensive new growth, so be prepared to use aggressive follow up with herbicide if you decide to burn.
4. Herbicide:
   a. Herbicide is only effective when the plant is actively growing, and when old thatch is not present. Remove thatch first by slashing, mowing or burning: remove and safely dispose of thatch.
   b. Spot spray small areas with glyphosate.
   c. More than one herbicide treatment is likely to be needed. Use herbicides in combination with vigilant follow up treatments.

Figure C5: a) Kangaroo grass. b) red-leg grass. Photo: J. Tann, c) Barbed wire grass. Photo: A. Chapman

African lovegrass

This summer-active perennial exotic is highly invasive. It is a Weed of National Significance (WONS), and can dominate grassy ground layers. Because it is not preferred by stock, overgrazing of other species allows African lovegrass to spread.

Distinguishing features

African lovegrass grows in two forms: a tussock form and a low-growing form. African lovegrass can be difficult to distinguish, especially from native *Eragrostis* species. If in doubt, consult an expert or herbarium. Plants are 20 – 120 cm high and densely tufted. Flower heads are large, spreading panicles from 6 – 30 cm long and up to 20 cm wide (Figure C6). At the base of the leaf around the stem (basal sheath), there is a conspicuous ring of hairs. Young seed heads are black or dark grey.

Look-alikes:
River (silver) tussock (*Poa labillardieri*)
Snow tussock (*P. sieberiana*)
Some native lovegrasses (*Eragrostis* spp.)
Paramatta grass (*Sporobolus africanus*)

The tussock form of African lovegrass looks similar to river (or silver) tussock (*Poa labillardieri*) and snow tussock (*P. sieberiana*). A key distinguishing feature is the young seed head of African lovegrass, which is dark grey or black, whereas the young seed heads of both *Poa* species are tinged purple (Figure C7a).

Figure C6: African lovegrass. Photo: J. Tann

Figure C7: African lovegrass look-alikes. a) Snow tussock. Photo: M. Bedingfield. b) Paramatta grass. Photo: J. Tann

Smallflower lovegrass (*Eragrostis parviflora*) has long, nodding seed heads that are also black or dark grey, but they are more delicate and the overall plant is usually smaller than African lovegrass. Paddock lovegrass (*Eragrostis leptostachya*) is a common pasture plant that is similar to the low-growing form, also with blue-green leaves. However, the seed heads of paddock lovegrass have short branches that stand out at right angles or slightly backwards from the main stem. Paramatta grass grows in spikes that do not branch out from the main stem (Figure C7b).

Basic biology

African lovegrass can produce a vast quantity of viable seeds and a persistent seed bank. Seeds can attach to stock, clothing, vehicles and equipment. It requires temperatures above 10 degrees C to germinate, and favours acidic, red and sandy soils. It is mainly summer growing but can set seed at any time of year if moisture and temperature are adequate.

Control options

1. Integrated management:
   a. Begin with management that prevents further seed set and reduces the infestation area.
   b. Use competitive perennial species such as kangaroo grass.
2. Physical removal:
   a. Only recommended for isolated plants or small infestations. Remove entire plants before seeding.
   b. If flowers have developed, bag flower heads first, then grub individual plants.
   c. Remove the base of the tussock with a mattock and minimise disturbance to soil.
   d. Dispose of plants safely, monitor and check for regrowth or seedlings.
3. Grazing:
   a. Intensive grazing in early summer keeps the plant in the vegetative and palatable stage.
   b. Avoid baring soil through grazing to prevent further establishment.
   c. Seeds can take 7–10 days to pass through livestock guts and can remain viable.
4. Herbicide:
   a. Herbicide is only effective when the plant is actively growing, and when old thatch is not present. Remove thatch first by slashing, mowing or burning: remove and safely dispose of thatch.
   b. Spot spray small areas with glyphosate diluted in water plus surfactant.

A good fact sheet about African lovegrass can be found on the Kosciuszko to Coast website: **www.k2c.org.au**. From the home page, navigate to 'Resources' then scroll down to find the African lovegrass fact sheet link. A simple web search for 'African lovegrass' will bring up quality management information from DPI Victoria, DPI Queensland, and the Northwest Weeds website.

Chilean needle grass

This grass typically occurs in temperate regions where the annual rainfall is greater than 500 mm.

Distinguishing features

Chilean needle grass is a perennial tussock grass that grows to about 1 m. Leaves are hairless and ligules are 3 mm long and hairless. Leaf edges are rough to the touch. Flowers are on long stalks above foliage and have a wind-blown appearance (Figure C8). Awns are long (60 mm 'tail') and pale green. New flowers are dark red in colour. Chilean needle grass has two types of seeds: stem seeds and normal seeds.

Figure C8: Chilean needle grass. Photo: B. Strong

Look-alikes:
Speargrasses (*Stipa* spp.)
Wallaby grasses (*Austrodanthonia* spp.)
Fescues (*Fetusca* spp.)

Figure C9: A spear grass (*Austrostipa* spp.). Photo: B. Strong

Chilean needle grass and spear grasses both have sharp seeds with a long, curved or bent awn and hairy tip (Figure C9). They can also appear red in colour before drying out. The key feature that distinguishes Chilean needle grass from native spear grasses is the corona between the seed and the awn.

Before they flower, green Chilean needle grass plants can look a lot like wallaby grasses and fescues, which are also green in winter. The main difference to wallaby grasses is Chilean needle grass's coarser and wider leaves. In contrast to fescue, Chilean needle grass has hairs along the leaf surface, and small tufts of hairs where the leaf blade and leaf sheath meet. Fescue has neither of these features.

Basic biology

Chilean needle grass grows mostly through autumn, winter and spring. Peak flowering time is late spring through summer, and in some cases into autumn depending on temperature and rainfall. Chilean needle grass seeds are long-lived and up to 15 000 seeds per square metre can be found in the soil under heavy infestations. The pointy seeds stick easily to fur, clothing and machinery and can injure livestock. Chilean needle grass is tolerant of drought, heavy grazing and some inundation. Mature plants are adapted to fire and will generally re-sprout.

Control options

1. Integrated management:
   a. Chilean needle grass is most vulnerable in the seedling stage, and is slow growing at this time.
   b. Spray topping, followed by crash grazing can help reduce large infestations.
2. Physical removal:
   a. Only recommended for isolated plants or small infestations. Remove entire plants before flowering or seeding. Destroy by incineration if possible.
   b. If flowers have developed, bag flower heads first, then grub individual plants.
   c. Remove the base of the tussock with a mattock and minimise disturbance to soil.
   d. Dispose of plants safely, monitor and check for regrowth or seedlings.
   e. Slash or mow before flowering and seed set. Note that slashing and mowing will not remove the stem seeds.
3. Burning:
   a. It is better to prevent seed set via grazing or herbicide.
   b. Burning at seed fall can be useful for infestations that have gone to seed. However, resulting bare ground is at risk of broadleaf weed invasion. Very small burns followed by dense native seeding may be an option.
4. Grazing:
   a. Young plants are palatable. Prevent flowering and seed set with strategic, high-density grazing. Allow long recovery times to encourage native perennials.
   b. Avoid continuous grazing that allows stock to overgraze more palatable species.
   c. Avoid baring soil through grazing to prevent further establishment.

5. Herbicide:
    a. The Queensland DPI has created an excellent fact sheet on Chilean needle grass chemical control options. You can find it at **www.dpi.qld.gov.au/4790_7226.htm**. Scroll down to find the Chilean needle grass fact sheet link.
    b. Herbicide is only effective when the plant is actively growing, and when old thatch is not present. Remove thatch first by slashing, mowing or burning: remove and safely dispose of thatch.
    c. Spot spray small areas.

Serrated tussock

Serrated tussock is a highly invasive, long-lived and easily spread exotic perennial tussock grass with no grazing value. The economic and environmental threat that serrated tussock poses makes it a Weed of National Significance.

Distinguishing features

Dense tussock with tightly rolled leaves and small serrations along the leaf edge. Leaves do not appear hairy at all. Ligules are white, hairless and about 1 mm long. The roots are long and fibrous. In autumn, serrated tussock plants are bright green when other plants have dried off. The previous year's seed heads do not remain on the plant. Awn is 25 – 35 mm long. See Figure C10.

Basic biology

Main germination and growth is autumn and winter, but growth is slow. Flowering is in spring, pod formation in summer, and seed drop in autumn. Serrated tussock forms very large seed banks. Most seed is only viable for about three years, but germinates easily with soil disturbance. Serrated tussock seed is very light and is spread by wind up to very long distances. Seed can also be spread by humans or animals on clothing, equipment, vehicles or fleece.

Management approaches

- Dense vegetation at the edges of paddocks can prevent further spread of seed heads by wind.

Figure C10: Serrated tussock plant (left) and seed heads (right). Photo right: L. Oliver

- Manage and reduce existing infestations:
  - Search for serrated tussock twice a year, each year.
  - Work from the prevailing upwind side of an infestation, and from isolated patches towards core infestations.

Control options

1. Physical removal:
   a. Chip out any individual plants with a mattock before seed drop. Do not chip out plants or cause soil disturbance where a seed bank has established.
   b. Plant a native in its place.
2. Pasture competition:
   a. Serrated tussock prefers disturbed or bare soil, and does not compete well with vigorous pasture plants.
   b. Use pasture competition in combination with other methods that kill plants or prevent seed set.
3. Herbicide:
   a. Herbicide creates bare ground, so only use herbicide as part of an integrated management strategy.
   b. Re-seed areas where serrated tussock has been sprayed, for example with kangaroo grass hay.
4. Fire:
   a. Fire will not kill serrated tussock plants but winter burns can significantly reduce seed set.
   b. Burn only small areas where adequate follow up can be done.
   c. Re-seed areas to provide competition where serrated tussock has been burned.

Broadleaf annuals

Exotic broadleaf annual plants such as Paterson's curse, St John's wort (*Hypericum perforatum*), capeweed and great mullein (*Verbascum thapsus*) are a problem because they outcompete many native perennial plants, including grasses and forbs. Exotic broadleaf annuals also reduce pasture productivity due to their low palatability. Some of these, for example great mullein and Paterson's curse, are toxic to livestock.

Distinguishing features

Many broadleaf annuals have a rosette stage before the main stem shoots and flowering. They are usually found in disturbed sites.

Look-alike:
Austral bugle

Paterson's curse can be confused with Austral bugle (*Ajuga australis*), a native forb. See Table C1 and Figure C11 for a comparison.

Table C1:
Distinguishing features of Paterson's curse and Austral bugle

Feature	Paterson's Curse	Austral Bugle
Flowers	Deep blue to purple, 20 – 30 mm long with five petals fused into a trumpet shape. New flowers at tip of flower stem. Flowers between July and January.	Flowers blue or purple, about 15 mm long, smaller than Paterson's curse, but with same overall form.
Rosette	Large, flat rosette of slightly hairy leaves with well-marked veins.	Basal rosette similar, but generally more erect.
Stems	Stout, erect, commonly 30 to 60 cm tall but often taller (rarely to 2 m), light-green, densely covered with coarse bristles, branching mainly towards the top.	Erect and about 15 cm high in the woodland form, taller in the grassland form. The leaves are up to 12 cm long, bluish underneath with toothed margins.

Figure C11: Paterson's curse (left) and Austral bugle (right). Photo left: S. Kotz. Illustration right: M. Bedingfield

Basic biology

Many of the broadleaf annuals are actually biennial, going through a rosette stage in the first year. After the rosette stage, these plants grow and flower very quickly, producing vast quantities of seed that are relatively long-lived. Many broadleaf annuals are able to grow and flower at a lower stature to avoid grazing and mowing. Species such as great mullein and khaki weed (*Alternanthera pungens*) have a large and long taproot.

Control options

1. Physical removal:
   a. Hand removal of single plants or isolated patches is effective if the entire plant and as much of the root system or taproot is removed with the plant.
   b. Remove plants when first detected, especially before seed formation.
   c. Bag any flower heads before removal.
   d. Because many broadleaf annuals are prolific seeders, minimise soil disturbance as much as possible during removal.
2. Nutrient management:

   Carbohydrate addition (Chapter 11) can be very effective on exotic broadleaf annuals, particularly when used in combination with seeding of native perennials.
3. Herbicide:
   a. Spot spray small infestations on actively growing plants if hand removal is not an option.
   b. Herbicide creates bare ground, so only use herbicide as part of an integrated management strategy.
   c. Establish grasses where broadleaf-specific herbicides have been used.
   d. Use broadleaf-specific herbicides only in areas where native broadleaf plants will not be harmed.
4. Grazing:
   a. Graze to favour native perennial species and increase or maintain ground cover.
   b. Build up humus and litter to reduce germination of weeds.
   c. Crash graze to prevent seed set at peak flowering times but do not create bare ground.
5. Fire:

   Fire is generally not effective on exotic broadleaf annuals such as Paterson's curse, capeweed, and St John's wort.

Appendix D. Planning and monitoring forms

Contents:

Indigofera australis. Illustration: M. Bedingfield

D1. Woodland features and condition score sheet

(Adapted from *Managing farm bushland* (Morsley and Trémont, 2000))

This form can be used or adapted to assess your patch or a specific part of your patch to determine management actions or to monitor progress at the patch scale.

Date: _____ Zone or Site: _____

Route walked: _____

NATIVE VEGETATION AND HABITAT

FEATURES	NIL 0	EDGES ONLY 1	ISOLATED INDIVIDUALS 2	PATCHES 3	ABUNDANT THROUGHOUT 4	SCORE	NOTES - MANAGEMENT ACTIONS
MATURE TREES							
TREE SEEDLINGS/SAPLINGS							
TREES WITH FRUIT/FLOWERS							
NATIVE SHRUBS							
YOUNG SHRUBS							
SHRUBS WITH FRUIT/FLOWERS							
NATIVE GRASSES							
GRASSES WITH FLOWERS ETC.							
NATIVE HERBS							
HERBS WITH FLOWERS ETC.							
LICHEN, MOSSES AND FUNGI							
STANDING DEAD TREES							
FALLEN TIMBER							
LEAF LITTER							
					TOTAL		HIGH SCORES ARE BETTER

WEEDS AND PHYSICAL DAMAGE

FEATURES	NIL 0	EDGES ONLY 1	ISOLATED INDIVIDUALS 2	PATCHES 3	ABUNDANT THROUGHOUT 4	SCORE	NOTES - MANAGEMENT ACTIONS
UNHEALTHY TREES							
INSECT DAMAGE							
MISTLETOE							
WOODY WEEDS							
NON-GRASSY HERBACEOUS WEEDS							
INTRODUCED GRASSES							
FERAL ANIMALS							
SOIL EROSION							
TRACKS							
					TOTAL		LOW SCORES ARE BETTER

D2. Vegetation walk-through monitoring sheet

(Adapted from *Managing farm bushland* (Morsley and Trémont, 2000))

Date: _____ Zone or Site: _____

Route walked: _____

TREES

Native and introduced trees (mature height > 5 m)		native or introduced	dominant, common occasional, rare	specimen number
				

SHRUBS

Shrubs (mature height 1-5 m)		native or introduced	dominant, common occasional or rare	specimen number
				

GROUNDCOVER PLANTS, A

Grasses and grass-like plants (e.g. grasses, rushes, sedges)		native or introduced	dominant, common occasional or rare	specimen number
				

D2. Vegetation walk-through monitoring sheet (cont.)

GROUNDCOVER PLANTS, B

Non-grassy herbaceous and woody plants (mature height <1 m)	native or introduced	dominant, common occasional or rare	specimen number
  			

ANIMALS

Actual sightings or evidence	native or introduced	dominant, common occasional or rare
 		

D3. Woodland management log

This form may be used or adapted to document management activities, and should be kept with the monitoring data logs. Make copies as necessary.

Zone or Site Description: _____ Manager: _____

Date: _____ Does this sheet continue from a previous Activity? **Y** / **N**

Purpose/Description of Activity: _____

_____

_____

_____

Procedure: _____

_____

_____

_____

_____

_____

Duration: _____ Follow Up Required? **Y** / **N**

Follow Up Date: _____

Follow Up Notes: _____

_____

_____

_____

_____

Adaptive Management: Is a change in the management approach necessary? **Y** / **N**

If Yes, Why? _____

_____

_____

What will be the new management approach? _____

_____

_____

_____

_____

_____

D4. Box gum grassy woodland monitoring log — photo points

Photographer: _____ Photopoint #: _____

Weather Conditions: _____ Date: _____

Notes about camera: _____ Time: _____

(GPS Reading: _____ S _____ E)

NORTH.
Notes:

EAST.
Notes:

Photo point monitoring log – page 2

SOUTH.
Notes:

WEST.
Notes:

D5. Quadrat monitoring sheet

Quadrat No: _____ Location: _____

Date: _____ Name: _____

Species Name (or if not known, general plant type or brief description e.g. forb, grass, moss, lichen etc.)	Description e.g. shape, size, number and position of leaves on stems etc.	Native/ Exotic	# Stems	Per cent Cover

Total number of species _____ Total per cent bare ground: _____

Appendix E. Useful links and other resources

Throughout this handbook, we have tried to list other resources, such as books, websites or organisations that may be of assistance in your management endeavours. This appendix compiles those lists and includes information about how to access or obtain the resources. It cannot list every book or website that may be of use, nor can it remain up-to-date forever. Our suggestions represent what we feel to be the most useful resources for a given topic. The resources listed here are correct as of April 2010.

Useful online resources and organisations

- **Florabank** (**www.florabank.org.au**) is Australia's premier resource for native seed information. This website allows users to find seed suppliers and collectors, determine which species are appropriate for a revegetation project, how to collect, handle and store native seed, and other useful tools.
- **Communities in Landscapes** (**cil.landcarensw.org.au**) is a project run by Landcare NSW with an alliance of 11 organisations. 'The project will inform and support management decisions in Box-Gum Woodland landscapes primarily through engaging land managers and their communities in practices that have positive outcomes for production and are known to benefit resilience in Box-Gum Woodlands.'
- **Grassy box woodlands Conservation Management Network** (**www.gbwcmn.net.au**). This group provides a framework and resources to manage and protect box gum grassy woodlands remnants. An excellent resource for those looking for other box gum grassy woodlands managers and advice.
- **PlantNET** online: plantnet.rbgsyd.nsw.gov.au/. This website is the The Plant Information Network System of the Botanic Gardens Trust. It is a collection of several databases of plant descriptions, herbarium collections, and keys. The New South Wales Flora Online link is easy to use.
- **Friends of grasslands** (**www.fog.org.au**) is a community organisation that provides advice and support to grassland managers. They conduct workshops and hold field days. Membership based. Website includes a fact sheet on grasses: **www.fog.org.au/Brochures/grasses_brochure.htm**.
- **Virutal Herbarium** (**www.csu.edu.au/herbarium**) provides high quality images of grassy-understory species. It is particularly helpful for grass identification. There is also a wealth of information on revegetation across the southwest slopes of NSW.
- **The Woodland Web** (**www.csu.edu.au/herbarium/woodlandweb**) 'contains a collection of articles describing recent research on the ecology, conservation, management and restoration of native woodlands and grasslands'. Some of the information is a few years old, but still interesting and relevant.
- The **Molonglo Catchment** (**www.molonglocatchment.com.au**) has compiled a list of 'freebies and downloads', which includes such titles as *Biodiversity in the Paddock: A land manager's guide*, *Serrated Tussock National Best Practice Management Manual, Managing for and recovering from drought - factsheets*, and many more.
- The **Understorey Network** (**www.understorey-network.org.au**) has excellent information on native understorey plants. Seasonal information may vary somewhat because this organisation is based in Tasmania. Do a Plant Database search using either common or scientific name.

- **Stipa** (**www.stipa.com.au**) is an organisation that aims to educate communities about and promote native grasses for conservation and production.
- **Flickr** (**www.flickr.com**) For many photos of grassy woodlands and both trees and ground cover species, have a look at the flickr website. In the search field, type 'grassy woodlands'. You may recognise some of the photos in this book!

Books

These resources are listed by type, then in alphabetical order by title. Many of these publications have been mentioned elsewhere in the handbook.

Field guides

Birds

- ***Field guide to the birds of Australia, seventh edition***, by K. Simpson and N. Day (2004). Penguin/Viking Publishers. One of the most popular bird field guides in Australia; available in most bookshops that stock nature publications.
- ***The field guide to Australian birds***, by G. Pizzey and F. Knight (2007). Harper Collins Australia Publishers. Another excellent field guide, available in bookshops or the Birding Australia website.

Reptiles

- ***A complete guide to reptiles of Australia***, by S. Wilson and G. Swan (2004). Available from book sellers or the Herp Shop: **www.herpshop.com.au**. Scroll down to 'Books' on the left, then click 'Field guides' at the top. Wilson and Swan have also written field guides to reptiles for Queensland and New South Wales.
- ***Reptiles and amphibians of Australia***, by H.G. Cogger (2000) is recommended by the Frogs Australia Network. Reed New Holland Publishers. The Frogs Australia Network also lists regional reptile and amphibian field guides on its website, **http://www.frogsaustralia.net.au/frogs/field-guides.cfm**.

Mammals

- ***A field guide to the mammals of Australia***, 2nd Edition, by P. Menkhorst and F. Knight (2004). Oxford University Press Publishers. The Australian Wildlife website (**www.australian-wildlife.com.au**) says: '...this book does just about everything right. Frank Knight's clear and beautiful illustrations and Peter Menkhorst's amazingly comprehensive knowledge have come together in what must be the ideal field guide for Australian mammals.' Available from books stores or the publisher.

Plants

- ***AusGrass – Grasses of Australia***, by D. Sharp and B. Simon (2002), is a comprehensive guide to identifying native and naturalised grasses in Australia. Package includes a CD and User Guide which includes interactive and dichotomous keys. Available from CSIRO Publishing at **www.publish.csiro.au** or 1300 788 000.
- ***Bidgee Bush - An identification guide to common native plant species of the South Western Slopes of New South Wales***, by K. Walker, G. Burrows, and L. McMahon (2001). This booklet describes the main species of trees, shrubs, herbs, forbs, grasses and climbers of the south-west slopes of NSW. Although focused on an area surrounding Wagga Wagga, many of the species listed occur throughout most of the box gum grassy woodlands range. Contact Greening Australia at (02) 6252-3035 for availability. A small charge may apply.

- ***Native wildflowers of the New England Tablelands of NSW: a simple illustrated key*** (2007). By Ruth Trémont. As described on the book launch field day:

  'Are you interested in identifying wildflowers but have no botanical training? Are you a land manager or outdoor worker asking what flowering shrubs or herbs are among your native pastures or in your natural areas? Would you like to have an easy-to-use field guide for the native flowers of the local area? Then this book is for you.'

  Available from the author at 'Tatibah', 250 Pine Forest Road, Armidale, NSW 2350 (02 6771 4630), from the Armidale Tree Group at 80 Mann Street, Armidale NSW 2350, Border Rivers-Gwydir CMA (Inverell) or Kanga Langa Books in Glen Innes.

Management guides

- ***Managing and conserving grassy woodlands*** (2002). S. McIntyre, J.G. McIvor and K.M. Heard. CSIRO Publishing. This is a standard reference and an indispensable guide for anyone wishing to manage grassy woodlands, especially in a whole-farm context. Available for $40 at **www.publish.csiro.au/nid/18/pid/4749.htm**.
- ***Managing farm bushland. A field manual for the Northern Tablelands of New South Wales*** (2000). By R. Morsley and R. Trémont. This is a very popular handbook published by World Wide Fund for Nature for land managers wishing to conserve and manage native bush on their properties. Available from the Armidale Tree Group at 80 Mann Street, Armidale NSW 2350 or by calling 02 6771 1620.
- ***Managing native grassland: a guide to management for conservation, production and landscape protection***. WWF publication. Available at **wwf.org.au/ourwork/land/publications/**
- ***Managing native pastures for agriculture and conservation*** (2004). By C.M. Langford, P.C. Simpson, D.L. Garden, D.A. Eddy, M.J. Keys, R. Rehwinkel and W.H. Johnson. NSW Department of Primary Industries. This book is available for **FREE** by contacting the NSW DPI Goulburn office at (02) 4828-6600. Includes common native grass species identification and herbage values, management advice, and much more. A very good resource for managers with native pastures.
- ***Stock and waterways: a manager's guide***, by J. Staton and J. O'Sullivan (2006). Available **FREE** through the Land & Water Australia website at: **lwa.gov.au/products/pr061132**, or by calling Canprint on 1800 776 616 and quoting product no. PR061132.
- ***Weed management guide for north west NSW***, by the Northern Inland Weeds Advisory Committee (2009). A comprehensive guide to noxious and other problem weeds in the North West NSW region. The NIWAC Weeds Booklet can be obtained for free by contacting the Regional Coordinator at the New England Weeds Authority on 02 6770 3905, or by downloading the document from their website (**www.niwac.org/pages/weed-management-booklet.php**).
- ***Wildlife in the home paddock. Nature conservation for Australian farmers***, by Roland Breckwoldt (1983). This very popular book can be difficult to find, but may be in your local library. It can also be found on some used book websites such as BibliOz (**www.biblioz.com**) or from Books & Collectables (**www.booksandcollectibles.com.au**). Includes information on corridors, wildlife, tree regeneration, pest species management.
- ***Wildlife on farms*****,** by David Lindenmayer and others (2003). Available through CSIRO Publishing (**www.publish.csiro.au**).

Revegetation guides

- ***A practical guide to revegetation in the mid Lachlan region***, by M. Sydes, L. Butterfield, and S. Rutledge (2003). Department of Infrastructure, Planning and Natural Resources, Orange.
- ***From seeds to leaves,*** by Doug and Robin Stewart (2000). CSIRO Publishing. Very good information on propagating and growing native plants.
- ***Growing Australian native plants from seed for revegetation, tree planting and direct seeding***, 2nd edition, by M. Ralph (2003). Murray Ralph/Bushland Horticulture, Fitzroy.
- ***Planting companion: a guide to native revegetation in the ACT region***, by L. Gould (2005). ACT Forests, Canberra.
- ***Revegetation techniques: a guide for establishing native vegetation in Victoria***, by K. Corr (2003). Greening Australia Victoria.

Technical guides

- ***Grassed up – guidelines for revegetating with Australian native grasses*** (2001). By C. Waters, W. Whalley, and C. Huxtable. Useful information about using native grasses in commercial applications, but includes chapters on seed harvesting, processing, storage, treatment and grass establishment. Available from NSW DPI at **www.dpi.nsw.gov.au** or by calling 1800 028 374.
- ***Australian native grasses: a manual for sowing, growing and using them*** (2009), by I.H. Chivers and K.A. Raulings. This book has 60 full colour pages with extensive notes on a range of Australian native grasses including specially bred types. Available from Native Seeds Pty Ltd (**www.nativeseeds.com.au**) under Resources/Books.
- ***Guidelines for the translocation of threatened plants in Australia*** (2004), from the Australian Network for Plant Conservation, is an in-depth and detailed guide for the keen land manager. The book is available from the ANPC website: **www.anbg.gov.au/anpc** under publications, or by calling (02) 6250 9509. *Note:* all translocation activities will require a permit from the relevant authority in NSW and Qld.
- ***Plant germplasm conservation in Australia: strategies and guidelines for developing, managing and utilising ex situ collections*** (2009). Edited by C.A. Offord and P. F. Meagher. Available through the Australian Network for Plant Conservation website at **www.anbg.gov.au/anpc** under publications, or by calling (02) 6250 9509.

White box road reserve. Photo: D. Carr

THE 15 BASIC PRINCIPLES FOR BOX GUM GRASSY WOODLAND MANAGEMENT

1. **Know your objectives, and keep them simple**
2. **Manage for patchiness**
   a. Manage for diversity
   b. Use a diversity of management
3. **Observe before you act, take notes and adapt what you do – forever**
4. **Use the precautionary principle** but don't let lack of knowledge paralyse you (consider Principle 5)
5. **When trying new approaches, test a small patch first** (this is the 'hair colour and carpet cleaner' principle)
   a. This principle does not apply to whole of patch activities such as retaining standing timber and bush rocks, no fertiliser and no cultivation
6. **Restore the basics before attempting to restore the details**
   a. For example, establish native perennials that can reduce nitrate levels before adding or working with forbs or rare species. But see principle 8.c. below
7. **Get the soil nutrient levels right**
   a. Keep soil carbon levels high – perennials are better
   b. Keep soil N and P levels low – mine it or lock it up in natives
8. **Maintain ground cover**
   a. Don't create opportunities for weed invasion
   b. Replace what you remove – when taking weeds out develop a strategy for getting natives back, but
   c. Some bare ground is needed to allow for native forbs to establish
9. **Prevent grazing of seedlings and grazing sensitive species**
10. **Minimise edge effects** for example, create a buffer or lower inputs in adjacent paddocks
11. **Keep the nutrient and water cycles across your whole property in mind**
12. **Use only locally indigenous or locally adapted species for plantings**
13. **Use herbicide sparingly** (see Principles 2 and 8 above)
14. **Seek advice, read widely and discuss your ideas with other grassy woodland managers**
15. **'Quick fixes' often fail – quickly**