Managing Your Bushland

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This publication was first produced in 1993 by the then Western Australian Department of Conservation and Land Management in collaboration with the Department of Agriculture, Western Australia and *CSIRO's Division of Wildlife and Ecology*, and with assistance from the Commonwealth Government and the Australian National Parks and Wildlife Service through the Save the Bush Program. *Managing Your Bushland* was written in 1992. At that time we deliberately aimed for a book in which the ideas underpinning management were explained so that managers had a solid framework for their work, could adapt suggestions for their situation, and could quickly identify what needed to be changed as new ideas arose. Although there have been important and major advances in knowledge over the past 16 years, the core concepts underlying management of remnant vegetation have changed surprisingly little. Therefore, while we are comfortable that the ideas in the book are still useful, there is new knowledge that changes some of the detail in the book, and would assist the bushland manager.

It is not our intention to re-print the book again – nor do either of us wish to produce the next edition. So, for someone out there, a challenge!

Penny Hussey and Ken Wallace (April 2009)

Cover photos:

Top: Western spinebill on Wilson's grevillea. (*Babs and Bert Wells/DEC*)
Left: Superb wandoo woodland managed for conservation and farm timber. York. (Penny Hussey)
Right: Wreath leschenaultia and common dampiera. Tardun. (Penny Hussey))

Back cover:

Fencing to limit root compaction, plus some companion planting, would help this fine salmon gum to survive. Trayning. (Penny Hussey)

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Department of
Environment and Conservation
Our environment, our future

Contents

1 Overview

Since settlement the replacement of native vegetation with crops and pastures has led to problems for both agricultural production and nature conservation in Western Australia. Most obvious have been hydrological changes, such as salinisation and waterlogging, and the extinction of some native plants and animals.

Protection of the remaining remnants of native vegetation, together with revegetation, are increasingly viewed as important ways of achieving sustainable agriculture and maintaining our unique plants and animals. Indeed, we are learning that nature conservation and sustainable land use are inter-dependent.

This book describes principles and guidelines for management of bush remnants for nature conservation. This information also has broad application to the management of bush remnants for land conservation. No attempt is made to cover those aspects of land conservation which would normally be undertaken on cleared land. These are dealt with in the many excellent publications produced by the Western Australian Department of Agriculture and others.

There are two types of management issues which affect remnants - those relating to the clearing and fragmentation of the original vegetation, and those relating to the introduction of exotic plants and animals.

Clearing and fragmentation of the original vegetation into small remnants have resulted in:

- changes in hydrology leading to increased surface soil salinity, waterlogging, flooding, and water erosion. The most dramatic effects are salinisation of waterbodies and loss of arable land.
- wind erosion of unprotected soils.
- reduction of the size of plant and animal populations so that they can no longer survive and reproduce. Sometimes this is because populations are so small that the death rate exceeds the birth rate, and sometimes because any disturbance, such as a wildfire, may lead to local extinctions. More often, extinction results from a combination of these and other factors.
- the lack of 'bush corridors' (vegetation which links remnants), making it difficult for many plants and animals to re-invade or effectively use remnants. Also, their small size and often narrow shape makes remnants very susceptible to external degrading influences such as the inward drift of fertilisers and weeds.

The second broad issue affecting the survival of native flora and fauna is the introduction of plants and animals. This has led to the frequent displacement of native species by either direct predation or competition for essential resources.

All of these factors are inter-related and together provide a serious threat to the long-term survival of bushland remnants and their flora and fauna. Most, and probably all, of these factors can pose a threat to sustainable agriculture.

The other very important factor which affects the long-term survival of remnants is human use. Depending on the size and other characteristics of a particular remnant, and the type and intensity of use, effects on nature conservation values will range from being insignificant to severe. Some uses, such as the extraction of sand and gravel, will have long-lasting effects. While commercial and other uses of remnants are chiefly outside the scope of this book,

their potential impact cannot be ignored.

Effective management of remnants is important for achieving sustainable agriculture and crucial for maintaining biodiversity in agricultural areas. Ultimately the fate of all remnants and their conservation values depends on how well we manage them.

The wealth of information obtained from farmers for this book indicates that there is solid rural concern for remnant management. If this book further contributes to the effective management of remnants for conservation, it will have achieved its purpose.

How to use this book

The book is divided into chapters dealing with different topics, which can be read alone or as a whole, as interest dictates. The chapters are cross-referenced, and there is an index of plants and animals.

Chapters 2, 3 and 4 are concerned with deciding the value of the bush remnant, setting management objectives and collecting relevant information. Chapters 5 and 6 deal with plants, firstly the principles involved in managing native flora and then how to deal with problem weeds and poison plants. Fauna management is discussed in chapter 7, while chapter 8 describes methods of problem animal control. One of the most important factors in bush management, the use of fire, is discussed in chapter 9, while chapter 10 deals with regeneration of degraded areas. The final chapter lists sources of further help and an appendix gives examples of actual management plans to achieve different goals.

In most chapters the specific issues are illustrated with examples from the agricultural region of Western Australia. In some cases these refer to the results of scientific research; in other instances practical advice from landholders is quoted.

To find out more about the topics in this book, turn to chapter 11. It contains a list of selected further reading, along with the detailed references from which each chapter's information was drawn.

The best help, though, consists of talking to people who are interested in the same topic.

Acknowledgments

This book could not have been produced without the willing help of many people.

We would like to thank especially those landholders who took the time and trouble to show us the remnant bush on their property and discuss features of its management. Many other rural residents gave us the benefit of their advice and described what type of publication they would find most useful. Professional scientists and others in government departments helped in many ways with advice and assistance, especially by critical comments on earlier drafts.

We would like to express our gratitude to all these people, too numerous to list. Without you, this book would not have been possible.

Illustrations

Grateful thanks to the several artists and organisations who provided the illustrations used in this book:

Louise Burch: illustrations on pp. 7, 12, 20, 22, 34, 39, 43, 45, 52, 57, 62, 64, 68, 69, 85, 90, 96, 106, 108, 154, 162, 165, 170, 173, 176, 177.

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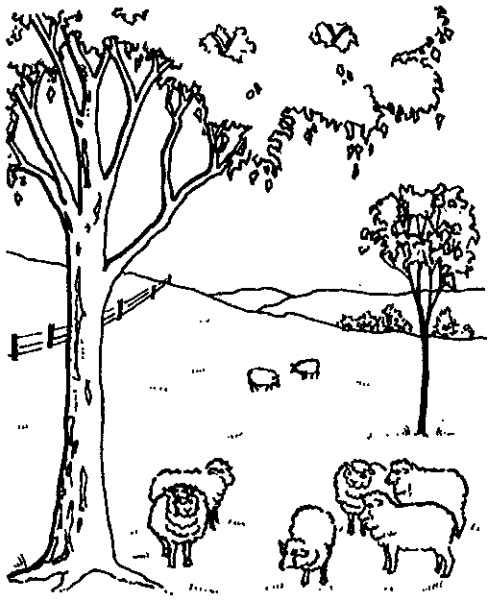
2 Values of Remnant Vegetation

- Preservation of local identity
- Historical record
- Recreation
- Conservation of flora and fauna
- Economic gain
- Achieving sustainable land use



The value of remnant vegetation will vary depending on one's interests and one's needs. For example, in agricultural areas, remnants located on erosion or saline-prone areas are valued for land conservation and their contribution to long-term economic gain. In other cases remnants are valued as reservoirs for our unique flora and fauna, or because they remind us of conditions faced by pioneers. A single remnant will have many values at the same time.

Another way of looking at the value of remnant vegetation is to say that the bush is valuable for itself. Many people express a deep conviction that although humans should be able to survive comfortably, other animals and plants have a right to survive as well. This attitude was beautifully summed up by Wally Shankland of Cadoux: "The farm has given me a good living and I've saved my bush too".

Also, what would be valuable if you were, say, a robin or a banksia tree? Looked at from these viewpoints, managing bush remnants can take on a whole new perspective.

To successfully manage land it is necessary to have a clear understanding of why it is being managed, that is, an understanding of the goals of management. Farmers regularly select which stock and crops they wish to manage, and whether to concentrate on a few commodities or maintain a diverse operation. These decisions give crucial direction to management and contribute to its success.

Similarly, to successfully manage remnants it is essential to understand why we want to manage them, and this is based on their values to us personally. Remnant values are discussed in this chapter to help people select appropriate management goals. Irrespective of the specific values

placed on remnants by any one individual, the contribution of such vegetation to achieving sustainable agriculture and protecting our unique flora and fauna are major themes underlying remnant value. Maintenance of biodiversity, including the conservation of our plants and animals, is increasingly perceived as important to achieving sustainable agriculture. In fact, these themes are more and more seen as two aspects of the same issue - our long-term survival.

Preservation of Local Identity

Apart from a few areas such as the Stirling Range, the agricultural region of Western Australia does not have outstanding and spectacular scenery. Instead it depends for local character on subtle changes in topography and in the natural vegetation community.

For example, driving north from Perth past Mogumber, you know that you have reached the Moora Shire - and the wheatbelt - when suddenly the salmon gums *(Eucalyptus salmonophloia)* appear. These magnificent trees convey a "sense of place" that is unique. As the mature trees die, it would be possible to replace them with, say, river red gums *(Eucalyptus camaldulensis)* derived from seed collected on the Murray in Victoria. Although they may grow as well as the salmon gums, they would not give the same feel of local identity.

Variety and local character are even more closely shown by shrubs, many of which might have quite a restricted distribution. People travel across half the world to see wreath leschenaultia *(Lechenaultia macrantha)* for example - this plant is an internationally-renowned symbol of the unique area which includes Morawa and Mullewa. If this and the many other unique plants are lost, very little remains which could confer a local identity.

For those lucky enough to have visited other countries where our eucalypts are commonly planted, the strong sense of being in Australia will underline the issue of local identity, and how easily it may be lost.

The bush provides visual diversity and adds a different dimension of beauty to the landscape, emphasising the bright green of growing crops and the gold of harvest. Its lack of order is a reminder of a much older world and a different rhythm of life. It is our species' wild past.

Remnant vegetation makes an important contribution to maintaining our local identity, and affects our ability to attract tourists. If we lose our place as the "wildflower state", then we will lose far more than our local identity.

Historical Record

Remnant vegetation is a living history book, showing what the country was once like. As one generation succeeds another on the farm, the patches of bush become ever more important as a benchmark emphasising the changes that have occurred.[1]

Already it is difficult to understand the hardships which pioneer settlers faced, and remnant vegetation provides some insight into the environment they confronted and the changes which have occurred since settlement. Understanding the history of the land helps us to better manage it for the future.

Recreation

Bush areas may be a distinct asset as a delightful picnic spot; indeed, that is sometimes why they were left in the first place. On the McColls' property at York, which was taken up in 1928, the children cleared a trail to Tadpole Rock, a granite outcrop about a mile from the house. It became, and has remained, a favourite play spot with its

rock pools and variety of attractive wildflowers. Originally uncleared and ungrazed because of the berry poison (*Gastrolobium parvifolium*) that grew in profusion, it remains as a picnic site for the family, a piece of heritage.

Most adults raised on farms will recall patches of bush which provided them with many hours of fun, and young children in particular find many opportunities for imaginative play among rock outcrops or scrubby thickets, while at the same time absorbing an appreciation for their natural heritage.

Conservation of the Flora and Fauna

Remnant vegetation is part of Australia's natural heritage. It contains the organisms that have evolved here over millions of years. Generally speaking, it is easy to destroy the bush, impossible to put it back together again in its original state.

Western Australia has one of the most diverse collections of plants in the world, many of which are found nowhere else. They are an extremely important scientific, educational and economic resource, and provide a home for our unique fauna.

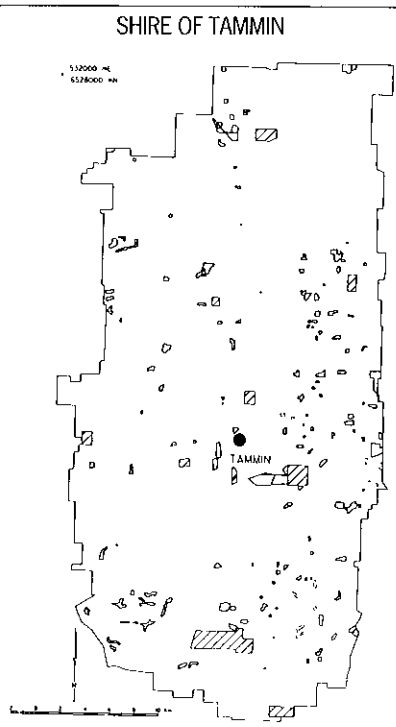
In much of the agricultural area, widespread clearing has meant that only small remnants are left in which to conserve our flora and fauna. Some of the bush remnants may be on public land such as reserves or roadsides but many of them, especially in the older settled shires, are on private land. Mapping of remnant vegetation areas by the Department of Agriculture shows clearly how little of the original plant cover now remains in some areas.

If we are to conserve our native flora and fauna, it is important that all remnants,

Figure 2.1 Tammin Shire was mapped by Anne Coates and the Department of Agriculture in 1987, from 1984 aerial photography.[2] It was found that:

Total Shire area (ha)	108 700
Total area of remnant vegetation (ha)	7 642
Area of remnant veg on private land (ha)	5 812
Area of remnant veg on public land (ha)	1 830
Per cent of Shire retained under native vegetation	7.0
Per cent of the Shire with public land retained under native vegetation	1.7
Per cent of the Shire with private land retained under native vegetation	5.3

Thus less than ten per cent of the Shire remains under native vegetation, and most of that is on private land. The map shows this distribution better.



including those on private land, be retained and managed so as to give wildlife every chance of survival (see chapters 5 and 7).

Rare Species

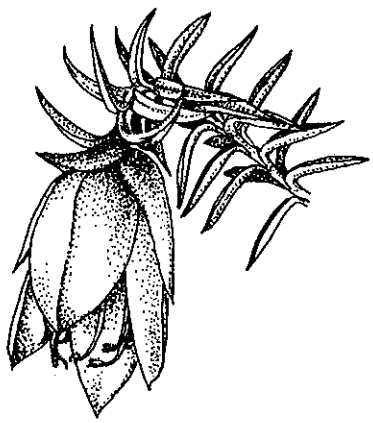
Because of widespread clearing, many plants and animals, once plentiful, are now rare and endangered. In the case of animals, many are very sensitive to alteration of their habitat, and have not been able to survive in areas where clearing has been extensive. The wheatbelt, for example, has lost 13 species of mammals, two species of birds and an unknown but probably very large number of insects, spiders and other invertebrates. Many other species are still hanging on in remnants but, unless positive steps are taken to manage the landscape to improve the fauna habitat, they will also ultimately disappear from the region.[3]

In the case of plants, about 53 species are believed to have become extinct in WA, most of these from the agricultural region. Many other plants are rare and threatened by extinction. Some of these only occur on private land or very vulnerable sites like roadsides. These sites are very valuable for conservation, for without them, the species would become extinct.

There are numerous landholders who are happy to fence off and manage sites with unusual vegetation on their property and these play a vital role in conserving our natural heritage.

It is also important to preserve habitat for fauna, especially where the animal numbers are declining. However, this often depends on a whole regional approach since animals - especially birds - are mobile and need to be able to move from one remnant to another seeking resources such as flowering plants. By increasing the availability of those resources rare animals may be encouraged to return to an area (see chapter 7).

The Narrogin bell[4]



The Narrogin bell, a subspecies of *Darwinia carnea,* is an example of a species threatened by extinction. This small, pretty shrub was thought to be extinct until it was discovered in a hilltop remnant within a wheat paddock on a property south of Narrogin. Together, the landowner and members of the WA Wildflower Society fenced off 0.25 hectares around the six remaining plants to exclude grazing by both rabbits and sheep. Thus protected, all the vegetation in the remnant persisted, and by 1984 there were 85 Narrogin bell plants. Since then, plant numbers have declined, perhaps because of droughts, so that by October 1990 the population numbered 36. More recently, a search of other likely habitats in the area failed to find any more populations. This site remains the only place where these plants are known in the wild (although they also are grown in Kings Park and gardens in Sydney).

If this site was cleared, Narrogin bells would no longer be part of WA's wild flora.

Conservation of Genetic Diversity

Populations of plants and animals are as varied as human populations, and those with a diverse genetic composition are generally more able to cope with change. If a population should become extinct, then its genetic inheritance is lost for ever. This explains the recent interest in conserving wild strains of crop plants as these are often very important in breeding programs, especially for factors such as disease resistance.

The genetic composition of populations at different localities may vary. They may even develop such distinct features that they can be called races. For example, the Port Lincoln ringneck parrot which occurs from South Australia through into WA, has a western race which is larger and has a green abdomen rather than a yellow one. In WA this is the bird called the twenty-eight parrot. Interbreeding between races can occur and this will tend to blur the differences.

It is important to conserve local genetic diversity as this will increase the likelihood that, if significant environmental change occurs, some individuals will survive and cope with the new local environment. Maintaining genetic diversity is also an advantage where plants are developed for commercial uses, an aspect that is dealt with later.

Economic Gain

Water Management

As is now well understood, the change in agricultural areas from deep-rooted perennial vegetation to shallow-rooted annual crop and pasture plants has caused a profound change to the soil water balance. Perennial trees and shrubs use water even during the summer, and thus ground watertables were held down. Removal of that vegetation has increased run-off and recharge, allowing the watertable to rise, causing seepage or waterlogging in susceptible areas and, where salt has been stored in the soil, salinity as well.[6] (See figure 2.3.)

It is not just trees that have deep roots and contribute to watertable management. Many apparently small shrubs have very much more growth below ground than they have above. For example, common buttercups (*Hibbertia hypericoides*) form an attractive rounded shrub seldom more than a metre in height. During studies at Eneabba, Marion Blackwell, a botanical consultant, found that it had roots 17 metres long! Thus passive clearing - allowing stock to graze in a remnant such that all the shrubs are destroyed - may contribute to rising watertables downstream.

Figure 2.2. Plants and animals declared threatened in Western Australia[5]

Group	Presumed extinct	Threatened
Mammals	11 terrestrial	27 terrestrial, 3 marine
Birds	2	35
Reptiles	0	7
Amphibians	0	2
Fish	0	2
Flora	53	260

Heavy rain falling on bare ground, such as may happen during a summer storm, causes soil erosion. In extreme cases, topsoil is lost and watercourses silt up. Growing vegetation breaks the force of the rain and its roots hold the soil, thus preventing erosion. Perennial vegetation along stream banks and other highly erosion-prone areas is valuable for this reason alone. Unfortunately, not enough remnant vegetation remains in many areas and replanting will often need to be undertaken. Figure 2.4 shows how specific nature conservation values can be added to these plantings; for example, by creating fauna habitat.

Where water management problems occur on a property, managing and rehabilitating existing remnant vegetation as well as planting deep-rooted perennials in strategic locations are good long-term land management options.[7]

Note that small animals such as dunnarts can drown in steep-sided wells or trenches dug to monitor ground water levels. If it is impractical to cap monitoring holes, place a large stick into the water, leaning against one corner, so that an animal that falls in can climb out again.

Reduction of Wind Speed

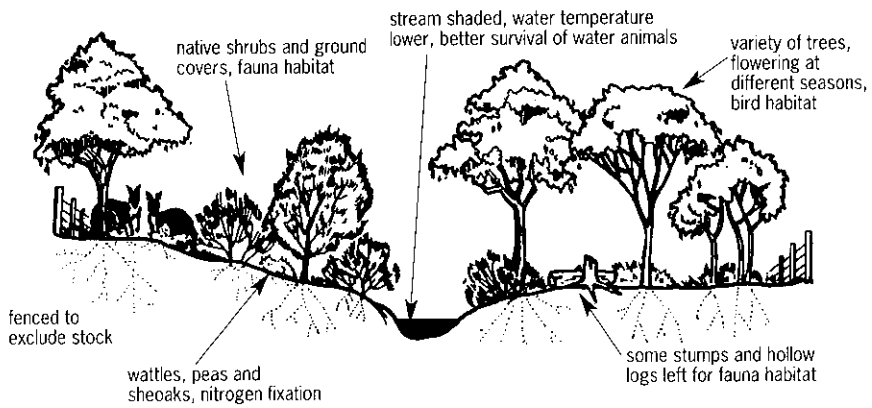
The extreme events associated with Cyclone Alby in April 1978 alerted the whole community to the problems of wind erosion. The sky turned red and soil from WA ended up staining the snow on mountains in New Zealand and Patagonia. However, even ordinary windstorms can cause problems.

Most agricultural land in WA experiences strong winds at some time in the year. The most obvious effect is the removal of topsoil in broad-acre farming areas; effects on livestock production are also important, though less well understood. Other effects include

Figure 2.3 Average annual water balance for a native vegetated and an agricultural catchment north-east of Newdegate (in mm)[8]

	Rainfall	Run-off	Evaporation	Interception	Recharge to ground water
Native vegetation	370	0	359	11	0
Agriculture	370	18	319	7	26

Figure 2.4 Creekline planting with nature conservation features



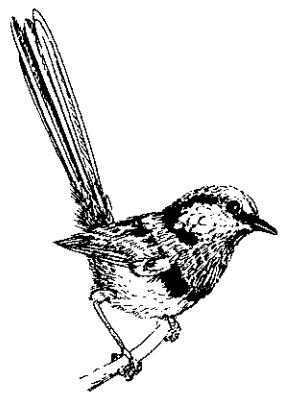
increased mechanical damage to unsheltered crops, and increased water loss from soil and crops. Remnant vegetation can act as a windbreak, and mitigate these adverse effects.[9]

Any remnant vegetation will have some windbreak effect, even that along roadsides, but often there are not enough remnants left and they might not be in the right place for maximum effect. In addition, trees alone can lead to a wind tunnelling effect, as can gaps in either remnant vegetation or planted windbreaks, which then cause more problems. Therefore it is likely that supplementary planting will be required to develop windbreaks.

Moderation of Temperature Extremes

In a climate that has periods of cold driving rain and periods of extreme heat, shade and shelter are valuable for maximum production from livestock. While shelter is most important at lambing time, and for off-shears sheep, increased production can result from providing shelter at all times, as, if an animal becomes too cold or too hot, it will use up food reserves to regulate its temperature. It will thus have to consume more food if it is to retain condition.

It has been estimated that an average of one per cent of off-shears sheep are lost to cold each year, though in some seasons this may be much higher. Lamb losses due to exposure may be as high as 15 per cent, or even greater where rain is combined with high wind speed. It is reasonable to assume that these losses could be halved with adequate shelter or almost eliminated if very well-sheltered haven paddocks are provided.[10] Off-shears sheep in summer can become very stressed and may die if shade is not available at temperatures over the mid-30s. They can also become severely sunburnt and at risk from cancer, especially



Erosion control - small bird habitat

After severe floods in 1963, Mary and Basil Smith of Wongan Hills commenced a programme of fencing off and replanting gullies. They chose a wide variety of trees suited to the soil type but found that many plants brought from other regions were badly attacked by beetles, and so no longer plant those species. Seed is collected from the best growing specimens on the farm for future plantings. Native shrubs such as manna wattle (*Acacia microbotrya*), *Grevillea paniculata* and others have regenerated in the fenced-off space, as have a number of native grasses and reeds. Weed control has not been necessary as the trees and shrubs suppress them.

No erosion occurs in the vegetated gullies, even during major summer storms. For example, 75 mm (3") at Christmas 1991 ran off Manmanning siding into a gully - and was held by the vegetation.

The area is also a superb nature conservation site supporting numerous birds, including breeding populations of the beautiful fairy-wren, chats, quail, larks, crested pigeons, kestrels and harriers.

around the tail in mulesed sheep.

Remnant vegetation can be important in providing this shelter, but degradation to the remnant will occur if it is so used (see chapter 5). Even occasional use for emergency shelter can lead to degradation and stock should not be permitted to remain long enough to trample or graze heavily. If they do, all the benefit of fencing the bush to allow soil structure to recover and the understorey to regenerate will be lost. It is probably better in the long run to design and plant shelter areas in appropriate locations.

Natural Pest Control

In a theoretical natural ecosystem plants and animals would be in a kind of dynamic balance. In fact, outbreaks of pests do occur, but they are followed by increases in numbers of their predators, so that the two populations tend to rise and fall in relation to each other.

In farmland remnants, pests, with far fewer predators than in earlier times, may increase out of all proportion, but it is difficult to predict the patterns which could be produced by many interacting factors.

Grasshoppers are an example of this. In the past they were preyed upon by numerous birds, from emus and ibis to butcher birds and grey shrike-thrush. But now bird numbers are reduced, and clearing has provided an increased number of sites for female grasshoppers to lay their eggs - as well as more grass for food. Of further concern is that some of the chemicals that may be used to control the grasshoppers when in plague proportions may accumulate in the bodies of any birds that eat them and so possibly could lead to their death too.

Encouraging a wide variety of animals which prey on insects to live in an area at least gives natural pest control a chance to operate. The story of New England Dieback is a case in point.

Mature trees in rural areas on the New England Tablelands, near Armidale in NSW, have been dying at an alarming rate. Many factors could be contributing to the tree stress (see chapter 5) but it was noted that the trees were annually being defoliated by scarabs and other leaf-eating insects. A major predator of scarabs in that area is the sugar glider, a small nocturnal marsupial that requires habitat trees with hollows for safe den sites. One sugar glider eats about 25 scarabs a night. But scarabs are only around for half the year, so in other seasons the sugar glider depends upon eating the sweet sap from acacias. However, stock grazing removes the acacias from beneath the trees, so fewer sugar gliders can survive. Andrew Smith, of the University of New England, has found that where acacias and habitat trees are plentiful there may be seven gliders per hectare as opposed to only one in grazed remnants.[11]

Seven sugar gliders could eat about 30 000 scarabs in a year - quite a respectable bit of natural pest control.

Something similar may be happening in the lower Great Southern with the devastating lerp attack on flat-topped yates (*Eucalyptus occidentalis*). Janet Farr from DEC, who is currently studying the problem, suggests several reasons, one of which may be that the lerp's natural predators are now fewer in number.

A lerp is the sugary cover produced by a psyllid, a tiny leaf-eating insect. They are preyed upon by birds, such as weebills, thornbills and pardalotes, and by parasitic insects. The small birds search for insects and their larvae within the crowns of trees and shrubs but they are not comfortable in open areas and do not usually work vegetation unless it includes a reasonably continuous shrub layer. Small wasps also parasitise the lerps, laying eggs in the larvae. The adults of these wasps need nectar in order to survive and search out lerps, so a reduction in the number of nectar-producing shrubs will decrease the number of parasitic wasps.

Thus in isolated trees, lerps, with far fewer predators, have built up to plague proportions.

The story is complicated by the fact that most flat-topped yates grow in swamps which receive a lot of nutrient runoff from the surrounding land, thus probably increasing the attractiveness of the foliage to leaf-eating insects (see chapter 5). In addition, many stands are under stress due to old age, which may make them less resilient to predation.

Where striated pardalotes can reach the affected trees and have learnt that lerps are good tucker, they can control the outbreak as has been demonstrated in a study plot near Cranbrook. In all cases, fencing to control grazing and permit regeneration of a diverse flowering understorey and, if possible, connecting remnants with bush corridors to encourage animal movement, should help.

Benchmark Research Sites

To fully understand how best to manage agricultural land it is important to know how farming affects both soil structure and composition. The best and cheapest means of doing this is to compare farmed land with uncleared land of equivalent soil type. In many cases remnant bush provides the only means of making such comparisons.

Production of Economic Items

Remnant vegetation can produce items of economic value to the landholder, but the potential varies greatly. However, if natural resources are taken from a remnant, it should be remembered that this will have some effect on the nature conservation values of that area. The significance of these effects will depend not only on the intensity, duration and type of use, but also on the management goals for the area.

Sawn Timber and Craftwood

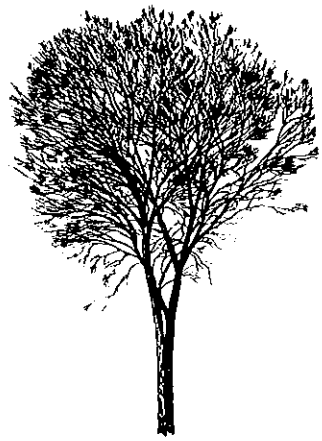
In higher rainfall areas, the production of sawlogs from native vegetation could be considered. However, the economics of the operation dictates a considerable investment both in area and in time, since it may well take 80-100 years for a tree to reach sawlog size (although new technology developed by DEC - VALWOOD® - is now able to use much smaller stems).

Karri (*Eucalyptus diversicolor*) and jarrah (*Eucalyptus marginata*) are the principal native commercial timbers that occur in farm remnants.

The early settlers used many timbers to create furniture and fittings that are beautiful, functional and uniquely West Australian. For example Buckland House at York, which was built in 1874, has a staircase of jarrah with a six metre handrail made from a beautifully-polished single piece of jam (*Acacia acuminata*). Increasingly, there is a demand by cabinet makers for quality craftwood, or speciality timbers. As well as occurring naturally within bush remnants, local plants could be used for economic production in planted windbreaks or bush corridors, or to manage water or salinity.

The type of tree chosen will depend upon the site and climate but might include: WA blackbutt (*Eucalyptus patens*), tree sheoaks (*Allocasuarina and Casuarina* spp.), the tree banksia species (including *Banksia menziesii, B. grandis, B. attenuata, B. seminuda, and B. littoralis*), forest woody pear (*Xylomelum occidentale*), Warren river cedar (*Agonis juniperina*), and wattles such as jam or mulga (*Acacia aneura*). Local officers from DEC will be able to provide further advice on these and other plants.

If naturally-occurring trees are being harvested from remnant vegetation, then a programme to replace logged trees should also be undertaken.



Rock sheoak (Allocasuarina huegeliana)

Forest woody pear (Xylomelum occidentale)

Candle banksia (Banksia attenuata)

Poles and Pulpwood

Poles or pulpwood give returns in a much shorter period of time, 10-30 years, depending on species and location. The trees in remnants are unlikely to be suitable for a commercial enterprise along these lines. However, there is no reason why a well-managed forest or woodland bush remnant should not be able to provide sufficient poles for on-farm use. The trick is to ensure that regeneration follows cutting (which will not occur if the remnant is grazed) and that the entire area is not cut before the regeneration reaches harvestable size.

Commercial tree plantations for poles or pulpwood could be integrated with bush remnants to buffer them from the effects of agricultural production and to create bush corridors.[12]

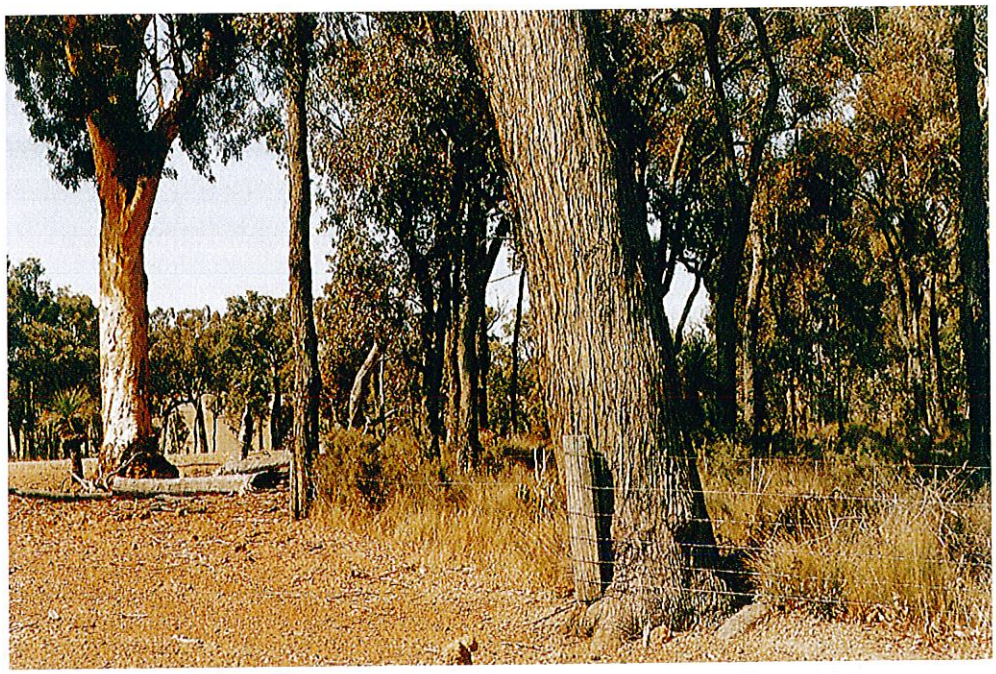
Native pole timbers found within remnants or that could be planted in association with them include karri, jarrah, marri (*Eucalyptus calophylla*), WA blackbutt, wandoo (*Eucalyptus wandoo*), brown mallet (*Eucalyptus astringens*), and yate (*Eucalyptus cornuta*). Note, however, that these trees are unlikely to reach SECWA pole standards when grown in drier locations at the limits of their normal range.[13]

Fencing Timber

Although fencing timber has now largely been replaced by steel posts in the wheatbelt, most farmers formerly grew their own, and almost all could do so. The service life of a fence post depends on the species used, whether it has been treated with preservative and the severity of attack by fungi and termites, with fungi being more important in wetter areas, termites in drier. Post timber is categorised into four classes of durability. In all cases the sapwood is not durable; it is the heartwood which confers the lasting qualities.[14]

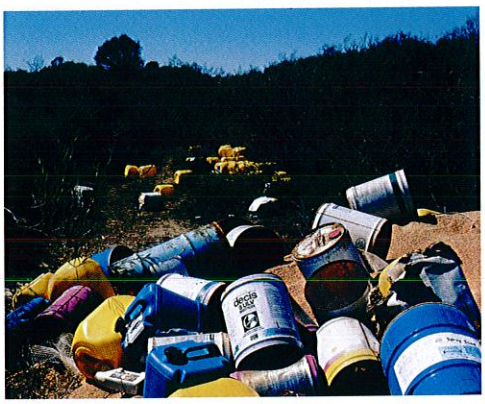
Remnant vegetation management and sustainable land use are interlinked. Narrogin.
(Department of Agriculture)

The important wildflower tourism industry depends on beautiful remnant vegetation along roadsides, like this one in the Shire of Victoria Plains.
(Graeme Rundle)



Above: *Control of grazing is essential for the long-term health of remnant vegetation. This paddock was cleared in 1973 and a remnant within it was fenced in 1974. Undisturbed by grazing, the vegetation remains in excellent condition. Note the economical fence construction. Boyup Brook.* (F. Ritson)

Right: *If there is a special feature, such as these rock pools with unusual water plants, consider how management of it can be fitted into the farm plan. Ongerup.* (Penny Hussey)



Below: *Thoughtless disposal of rubbish, especially farm chemical containers, downgrades remnant vegetation and could pose a threat to human and animal health. Mullewa.* (Penny Hussey)

Durability of timber for fence posts:
Class 1 - highest natural durability with a life of 25 years or more, for example: powderbark wandoo (*Eucalyptus accedens*), inland wandoo (*E. capillosa*) and wandoo (all often called white gum), jam.[15]

Class 2 - high natural durability with a life of 15-25 years. Preservative is useful to extend post life. Examples include sheoak (*Allocasuarina fraseriana*), yate, jarrah, WA blackbutt.

Class 3 - moderate durability, seldom lasts as long as 15 years. Preservatives are necessary if these species are to be used for posts. Examples include brown mallet, marri, bullich (*Eucalyptus megacarpa*), salmon gum.

Class 4 - low durability with a life of only a few years. No native timbers in this class are used.

In 1930 a fence post trial was set up at Wickepin to test the value of the various preservatives then in use for retarding termite attack. Reassessed in 1987, the untreated wandoo and jam posts included had outperformed everything else, with the wandoo posts still having a good ten years of life in them. The next best performer was marri treated with creosote and oil.[16]

Clearly, although modern preservatives should increase the life of less durable timbers as in the case of brown mallet there is a cost (and effort!) advantage in using white gum strainer posts. In suitable areas, regeneration could be encouraged in dense stands (for straight growth) by burning heaps to create ash beds (see chapter 9) so that saplings are coming on every few years and a variety of different sized posts are always available.

Jam is very widespread and is one of the easiest acacias to grow. Using regeneration burns, it would be possible to manage a large remnant such that suitable numbers of jam posts were either continually reaching cuttable size, or else large numbers were coming to maturity at the time that fences would need renewing.

Non-durable timbers, provided they have a sufficiently wide sapwood band to absorb the chemical, can be treated with preservatives to increase their durability. DEC's Gary Brennan is currently evaluating methods for doing this and developing recommendations for applying them to local timbers of durability class 2 and below.

Fuelwood

Until recently it has been considered that timber for wood-burning stoves has been abundantly available throughout WA, but it is now becoming clear that this is not so. Urban dwellers pay high prices for firewood, and this trend will probably continue.

A problem with the use of fallen wood from remnants as fuelwood is that this timber adds an important extra habitat for fauna (see chapter 7). Some species only live in areas where there are fallen logs, especially hollow ones. In addition, decomposition of the timber is part of the nutrient cycle within remnants.

Commercial fuelwood production, then, is probably best left to plantations of suitable trees, perhaps planted in buffers, shelter belts and bush corridors in association with remnants. In drier areas, the South Australian tree, sugar gum (*Eucalyptus cladocalyx*), is a good tree to consider if planting for this purpose. Once established it can be coppiced, giving a steady supply of fuelwood plus continuous stock shelter. Alternatively brown mallet is fast-growing and produces pole-like stems that are convenient to cut for fuelwood or treat with creosote for use as a fencepost.

Within a bush remnant, individual firewood collection should be done with care, creating the minimum disturbance and leaving hollow logs where they are.

The most popular commercial fuelwood is jarrah because it is easy to split and burns

to charcoal which is easy to clean from fireplaces. Marri is hard to split and its gum may block stove chimneys. In addition it burns to white ash which can blow into the room.

Sandalwood (*Santalum spicatum*) is extremely aromatic when burnt, but it is far more valuable when sold overseas and burnt as joss-sticks. Stinkwood (*Jacksonia sternbergiana*) is not recommended for burning as it has the most repulsive smell, of unwashed urinals!

Medicinal Plants (including leaf oils)

Australian native plants have never been properly surveyed for their possible economic significance. For example, native wattles and grasses could become important fodder plants. Many vital medicinal drugs are derived from plant products. The Aboriginal people used local plants in this way and much of their knowledge has never been scientifically investigated.

The production of eucalyptus oil was once a thriving small industry in Australia, but now is carried on mostly from plantation-grown trees overseas. Nevertheless, many native plants produce oils which could have a commercial value for medicinal or industrial use.[18] In many cases locally-occurring species would be suitable, and oil production could be combined with some other function such as windbreaks. Research continues into development and marketing; contact DEC for up-to-date advice.

Wildflowers and Seeds

Many species of native plants have commercial value as cut flowers, and native plant seed is saleable or can be used for revegetation work on local properties. However, before production of these items from remnants is undertaken, a number of basic points should be considered.

Tail bush - a cure for AIDS?[17]

Recently researchers from an American drug company requested quantities of tail bush (*Anthocercis littorea*), a common plant in coastal scrub, for testing to see if a chemical it contains could be useful as a drug to counter AIDS. If it is found that it does contain a valuable drug, it will be of benefit to millions of people worldwide.

Twenty years ago no-one had heard of AIDS, so no-one could predict that tail bush might become a lifesaver. We should guard against extinctions; they result in the loss of our genetic resource.

Legal points:

- All native flora in WA is protected under the Wildlife Conservation Act. Landowners and occupiers may take protected flora from their land, but in order to sell it the person must hold a Commercial Producer's Licence, obtainable from DEC. (This applies whatever portion is being sold - flowers, foliage, seeds or whole plants.) A person holding this licence must produce quarterly returns for DEC detailing the flora taken for each month.

- It is necessary to be able to identify what is being picked, for seeds especially, to the correct Latin name at species level, as they are not saleable unless accurately identified. In addition, under the Wildlife Conservation Act, DEC can require the holder of a licence to provide a specimen of plants collected to verify that the correct names are being applied. This is most often requested where plants are difficult to identify or a commercially pickable species may be similar to a rare one.

- Declared Rare Flora may not be taken, even from your own land, without a permit from the Environment Minister. It is extremely unlikely that this would be given for commercial collection.

Marketing points:

- The native cut flower market is very particular with regard to type, standard and quality of blooms. To avoid the loss involved in taking unsaleable material, it is advisable to establish a market beforehand, and be certain of exactly the type and quality of material needed. Note that most wild-cut material - that is, material cut from remnants - is of variable quality and may not attract a premium price. It may, in fact, be unsaleable. Remnant vegetation needs to be managed if it is to produce higher quality flora. If collecting a sample of cut flowers for a buyer, it is important to ensure the sample is representative of the quality available.

  Managed plantations typically provide better returns through higher yields and a better quality product.

- Some seed, for example grevilleas, is scarcer and more difficult to collect than other types and therefore commands a higher price. Common species may have little commercial value. Discuss with a person involved in the industry which species are likely to give you the best returns for the labour involved.

Flora management points:

- Production of plant products from a remnant should be done on a sustainable yield basis so that the resource will continue to be available into the foreseeable future. However, harvesting any portion of a plant puts pressure on it and leads to stress or death of the plant if not done correctly. Seek advice from DEC, the Department of Agriculture or the wildflower industry concerning the best way to harvest for maximum marketability and minimum plant damage. Note that for exports Commonwealth legislation requires that flora destined for export must be harvested in a sustainable manner.

  An example of a flora management plan, managing showy dryandra for cut flowers, is shown in the appendix.

- With some large-fruited plants, such as hakeas, it would be possible to remove every single seed from an individual plant. However, that would eliminate the plant's chances of survival should a disturbance such as a fire affect the area. Always leave some fruits on the plant to

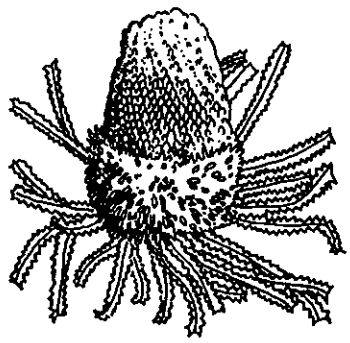
fall naturally - half to pick and half for the plant is a good rule of thumb. (See chapter 10 for details of seed collection.)

- When picking, take care not to cause mechanical damage to other plants.
- Diseases such as *Phytophthora* dieback can devastate native plant communities. If the area to be picked lies within the range of the disease, greater than 400 mm rainfall, see map on page 70 ; and especially if it is a community which contains plants of the banksia family, anyone entering the area must follow dieback hygiene procedures (see chapter 5). If this is not done, a potential source of income for generations could be wiped out in a few years. The long-term gains are well worth the short-term hassles.

Summary:

- First learn what is in your remnant bush (see chapter 4) so that you can then decide if there is anything of commercial value - contact the Flora Industry Advisory Committee, c/- DEC.
- Determine markets for the quality/quantity available.
- Determine a picking strategy that maximises returns and minimises damage.
- Get a licence from DEC before you start picking for sale.
- Manage the bush so that the desired plants can flourish. (Remember: if you are to collect seeds, there must be suitable pollinators present and able to visit the flowers!)

Flower harvesting and nutrient loss



Some plants growing in nutrient-poor environments such as the Western Australian sandplains, appear to store more nutrients in their leaves than do plants in more fertile areas. It is suggested that this storage helps growth and reproduction during adverse years.[19]

During a study on the effect of commercial harvesting on the growth of Hooker's banksia (*Banksia hookeriana*) Frank Obbens of Curtin University studied the nutrients available to the plant and found that there were significant losses. Fifty-three per cent of the plant's canopy nitrogen store and 62 per cent of its canopy phosphorus store were removed with harvested blooms. This is equivalent, over the eight years these stands had been picked, of 3.34 kg/ha of nitrogen and 0.16 kg/ha of phosphorus.[20]

Clearly, for the long-term survival of this community, at some stage a manager would have to look at nutrient replacement.

- The uses described above will inevitably have an impact upon conservation value. Monitor the use and adjust management as necessary.

Increase in Property Resale Value

Reports from Victoria indicate that properties which include good quality remnant vegetation are attracting a premium price - up to ten per cent on the going rate in some cases.[21]

It is likely that such trends will also manifest themselves in WA. Many property advertisements already use comments like "well treed" as selling points.

Honey

Remnant vegetation often has numerous flowering plants that can support hives of honey bees. However, there is evidence that honey bees, which are not native to Australia, can compete with native animals for resources and thus have a detrimental effect on nature conservation values. This issue is considered in more detail in chapter 8.[22]

Tourism and Farm-stay Holidays

Australia is the most urbanised nation on earth, with over 80 per cent of our population living in cities. An increasing number of urban residents are finding that a holiday spent on the farm is a delightful change and an experience they would like their children to have. In certain favoured tourist areas, such as the Leeuwin-Naturaliste Ridge, the income generated by these visitors can become a substantial part of the farm revenue. In most areas where farm-stay holidays have been established the returns have proved to justify the investment.

Accommodation offered is as various as the clientele it is hoped to attract, from a paying guest in the homestead, through very basic (for example shearers' quarters) to luxury rammed-earth cottages. Most, though not all, farm-stay holidays are self-catering. Apart from any local attractions that could be visited, a big draw-card is natural bush on the property through which the holiday-makers could walk, cycle or horse-ride. Being able to promise a variety of wildflowers, birds and mammals is a positive selling point.

Many coach companies offer wildflower tours and, if a property is on a major tourist route, there is the possibility of catering for a stopover - say, lunch or afternoon tea - for one of these groups. There would need to be an outstanding wildflower area - possibly some sandplain - easily accessible to a coach, and a guide to explain its interesting features.

Another possibility is providing a site for a school camp - for example for high school biology or geography - where the juxtaposition of agricultural activities and good quality remnant vegetation would permit a number of student study opportunities.

Even if the idea of catering for tourists does not appeal at the present time, the maintenance of good quality remnant vegetation provides more options for the future.

Mining and Rubbish Disposal

Remnant vegetation is frequently used as a rubbish disposal site or source for materials such as sand and gravel. These uses degrade the value of remnants for most other purposes, and given the dearth of remnants such use could rarely be considered appropriate.

In the case of mining, it should be stressed that these uses tend to focus on a particular vegetation type, and that while mined areas may be rehabilitated, it is not possible to replace the complete vegetation community.

Achieving Sustainable Land Use

Anyone who has lived in agricultural areas of the south-west for over twenty years appreciates that we are still working towards achieving sustainable agriculture, and the substantial degradation of similar agricultural systems elsewhere in the world is a warning that we ignore at our peril.

An advantage that we have over other countries is that, with some notable exceptions, we have retained the greater part of our natural resources. We can ill afford to lose further natural resources, along with the present and future options they represent.

In a changing environment, remnant vegetation increases local diversity in a way which improves the resilience of local ecosystems to change. Some agricultural researchers are suggesting that we model our agricultural systems on natural ones to help ensure that they are sustainable,[23] and we cannot afford to lose the remaining fragments of our natural ecosystems. In addition, rehabilitation, revegetation and linking patches are crucial to maintaining our current biodiversity and achieving sustainable land use.

3 Planning

- Management objectives
- Collecting the information
- Plan of action
- Recording the results and monitoring
- Plan for a regional conservation network

Management of bush remnants starts with a clear vision of why the land is being protected. Implementing management requires planning.

Farmers follow a planning process constantly as they organise the use of their land, paddock by paddock, often with plant rotations of several years in mind. The major difference with managing bushland is the timescale involved - 10, 20 or even 100-plus years to the maturity of the plants. Because of its long-term nature, it is essential that a plan be thought out carefully.

All management plans should include:

- written objectives (what you aim to achieve)
- relevant background information
- written plans of action (how you will achieve your objectives)
- plans for monitoring and evaluating results.

It would be a good idea to include the bush management plan at the same time as doing a whole farm management plan.

Management Objectives

The objectives of a management programme should be clearly defined. To do this, first decide the values and uses proposed for the remnant (see chapter 2).

Some examples of objectives might include:

- to protect and conserve native plants and animals and their habitat
- to protect and conserve particular rare plants or animals and their habitats
- to protect special features of the landscape, for example a rock outcrop or a wetland

- to preserve an attractive picnic area
- to preserve an example of natural heritage for future generations
- to provide a windbreak for stock and crop
- to protect an erosion-prone creekline
- to reduce waterlogging
- to decrease recharge within a saline-affected catchment
- to provide native plant seed, fencing timber, or other commercial products.

Note that any one remnant could meet several of these objectives and an interconnected network of remnants would be even more effective.

Collecting the Information

It is important to collect together as much information as possible about the remnant. Methods of doing this are considered in detail in chapter 4.

What to Do if the Information Isn't Available

It may not be possible to collect all the data it would be useful to have. There may not even be answers to obvious questions such as "what will be the effect of a fire?" Remnant vegetation patches are often small and isolated, so management actions - such as a fire - have a relatively greater effect than on an extensive patch of bush. There is less margin for error.

It is probably best to undertake specific management action only if there is a good reason to do so. Be cautious and avoid unnecessary actions.

- Avoid large scale disruptions such as a fire which burns the entire remnant - trial a section first and observe the result,
- Minimise activities which disturb the soil or introduce nutrients, as these encourage weeds.
- Act only after careful consideration and record results.
- Share your knowledge with others so that we can all learn. For example, you may like to contact any of the biodiversity extension officers working with DEC's Land for Wildlife programme, Greening Australia, the National Trust (WA) or WWF-Australia.

Plan of Action

One way of deciding what to do is to undertake the following steps:

1. Write down the objectives.
2. List all the actions that may be used to achieve these objectives.
3. Work out which actions are most important.
4. Determine what resources (money, materials, knowledge, etc.) are needed to undertake the actions.
5. Rank actions according to importance and resources, and write them down with a schedule.

There are two types of rankings involved - ranking between remnants and ranking of actions. Ranking of actions will largely reflect the resources available and those activities which are most important for maintaining remnant values or preventing further degradation (for example, remove grazing).

Ranking of remnants can be done in a number of ways. A method of ranking for nature conservation value on a State-wide basis is shown in figure 3.1.[1] Another way of approaching this issue is to select those remnants which are easiest to manage (generally the least degraded). This can be determined by allocating remnants to one of four categories (see figure 3.2).

If possible, management should aim to raise each patch of bush to the next highest category.

Figure 3.1 Remnant vegetation protection scheme: classes of vegetation

	VEGETATION CLASS	REGION 1 CENTRAL WHEATBELT	REGIONS 2 AND 3 NORTHERN AND SOUTHERN SANDPLAINS	REGION 4 FOREST
VERY HIGH PRIORITY	CLASS 1	• Woodlands of banksia or salmon gum • Shrublands on sandy soils • Freshwater wetlands • Brackish wetlands • Vegetation on greenstone or quartzite outcrops	• Woodlands of salmon gum • Freshwater wetlands • Brackish wetlands • Vegetation on greenstone or quartzite outcrops	• Woodlands • Mallee vegetation • Freshwater wetlands • Brackish wetlands • Vegetation on granite outcrops • Vegetation on greenstone or quartzite outcrops
HIGH PRIORITY	CLASS 2	• Woodlands of wandoo or blue mallet • Mallee on loams and clays • Shrublands on gravelly soils • Vegetation on granite outcrops	• Woodlands of powder bark wandoo, silver or blue mallet • Mallee on loams and clays • Shrublands on gravelly soils • Vegetation on granite outcrops	• Woodlands of tuart or yate • Shrublands on gravelly or clay soils
MEDIUM PRIORITY	CLASS 3	• Woodlands of jarrah, marri, brown mallet and sheoak • Mallee on sands or gravels • Shrublands of wodjil, tamma or broombush	• Woodlands of jarrah, marri, banksia, brown mallet or sheoak • Mallee on sands or gravels • Shrublands on sandy soils	• Woodlands of powder bark wandoo, marri, wandoo, Albany blackbutt or sheoak • Shrublands or sedge-lands on wet flats • Shrublands on coastal sand dunes
LOW PRIORITY	CLASS 4	• Wetlands of samphire • Wetlands of saltpans • Wetlands of creek lines	• Wetlands of samphire • Wetlands of saltpans	• Woodland or forest of jarrah • Wetlands of salt pans • Wetlands of creek lines

Figure 3.2 A classification of remnants by the amount of management needed

CHARACTERISTICS	MANAGEMENT NEEDED
1. Excellent Remnant • Intact community, all expected plant layers present and healthy • Little or no history of grazing • Almost no disturbance or disturbance confined to a small area • Few weeds or localised only	**Self-Maintaining** • Fence to exclude stock • Control exotic animals • Ensure that external factors do not contribute to degradation.
2. Good Remnant • All expected plant layers present, but sparse and may show signs of stress • Moderate grazing pressure • Change in soil structure evident, but not widespread • Weeds may be extensive, up to 50 per cent of total area	**Minimise Factors Causing Disturbance** • Fence to exclude stock • Control exotic animals • Encourage natural regeneration • Control weeds
3. Moderate Remnant • Plant community simplified, often with shrub and ground layer sparse or absent • Heavy, prolonged grazing pressure • Change in soil structure and/or water balance evident • May be signs of erosion, salinity or waterlogging	**Rehabilitate** • Fence to exclude stock • Control weeds • Fix up by whatever means feasible whatever is causing the erosion, waterlogging or salinity • Replace shrub and ground layer using a combination of planting and direct seeding
4. Fair Remnant • Plant community severely altered, few remaining original species, may show severe stress, may be dead or dying; replaced by weeds, or swamp- or salt-tolerant plants • Very heavy grazing or salinity or waterlogging	• Fence to exclude stock • Control weeds • Control salinity or waterlogging • Revegetate with species appropriate to the present nature of the site

Below is an example of a remnant management plan. It gives examples of some topics that management plans should address.

In the appendix are examples of some management plans produced for specific objectives by various individuals and organisations. They could be used for ideas.

An Example of a Remnant Management Plan

Objectives

- maintain and enhance the conservation value of a jam and York gum (*Eucalyptus loxophleba*) remnant
- prevent the further spread of a salt scald.

Information and Priorities

Information was gathered from books, neighbours and government agencies. Financial and labour resources were assessed along with the cropping programme and other relevant parts of the farm plan. Priority was given to those actions that were essential to increasing vegetation cover and halting the spread of salt, and to those required to attract birds for nature conservation and pest control. A shrub layer was perceived as essential to implement these strategies, and species selected were local and those most likely to spread naturally.

Plan of Action

Year 1
- fence the remnant
- control rabbits
- collect melaleuca seed
- prepare site for planting and direct seeding.

Year 2
- plant seedlings of swamp sheoak (*Casuarina obesa*) and spread melaleuca seed, collected from a natural salt area on an adjoining farm, along edge of salt scald
- control weeds in part of remnant, create small heaps for burning.

Year 3
- burn heaps, seed them with local trees and shrubs, undertake weed and rabbit control as necessary.

Year 4
- assess progress and re-write plan and objectives.

Monitoring and Evaluation

- find readily identifiable places for photos of the vegetation and the salt scald
- place a line of stakes along the edge of the salt scald and measure its advance/retreat
- count survival of planted seedlings
- children to list and count bird species four times a year - possibly to be used as a school project
- social rabbit shooting: keep a record of rabbit numbers sighted and shot.

Recording the Results and Monitoring

Monitoring the effects of management is important because:

- Western Australia is so vast and varied that there are no hard and fast rules like: "Do this, and it will work". Rather, the statement has to be: "Try this, and it should work". Thus it is important to keep a record of what happens after any management action, so that an understanding of the effect of different procedures can be built up. Climatic factors and events such as insect plagues should also be recorded as they, too, have a profound effect on the results.
- In order to check whether the management is having the desired effect, repeated observations and records are essential.

Record keeping can be as detailed as time and interest permit but some record is essential for effective, long-term management.

It is also useful if a diary or log book is kept for the remnant. Management actions could be noted in it, together with the date and extent of events such as a fire or a locust plague, as well as opportunistic observations such as bird records and flowering of particular species. Photographs, with the date they were taken, could be mounted in the log book for future reference, and pressed plant specimens stuck in next to their name. This way a record will accumulate that will be invaluable in determining the best way to manage the area.

Change the Plan if Necessary

Always be ready to update your plan in the light of new information. A new chemical could be released, for example, which would be excellent for weed control, or a new technique for regeneration proved by trials.

Plan for a Regional Conservation Network

It is a good idea to discuss the plan with your neighbours, so that the plans for the catchment and region are integrated, and everyone learns from each other.

No piece of land, no plant or animal, exists in isolation. To be truly effective, land care and the conservation of Australia's natural environment should be considered on a regional basis. If planners and land managers at all levels consider conservation as part of a multiple use concept for the land under their control, then the long-term retention of Australia's natural biological diversity is more likely to be achieved along with sustainable agriculture.

The Department of Planning and Urban Development recognises that consideration of environmental issues in a multiple use framework should be an integral part of planning at the State and Regional Planning levels.[2] Local Government Authorities could also adopt this approach as, for example, Serpentine-Jarrahdale Shire Council has done.

The preparation of plans by Catchment Groups or Land Conservation Districts provides a great opportunity for incorporating nature conservation into practical farm planning. Koorda LCD and Greenbrook Catchment Group (Mingenew LCD) are creating herbaria of local plants, while Inering Catchment Group received a grant to enable them to determine the management priorities for bush remnants in their area.[3]

If groups of landowners work together on farm and catchment plans, then, as shown in the following chapters, some nature conservation value can easily be incorporated into the plan, and a regional conservation network developed.

4 Collecting the Information

- The site
- The plant community
- The animal community
- The history

Managing an area without knowing much about it is a chancy business. The more information available, the better the management decisions are likely to be.

Create a file or notebook especially for the remnant and record in it all observations and actions affecting the bush. Identified plant specimens could be mounted in it, as could photographs for later comparison. This will become a fascinating record.

The rest of this chapter describes the sorts of things that could be recorded in remnant vegetation, and how they could help with its management. Many of them would make superb school projects if there are any students in the family.

The information that is most urgently needed for management is marked with an asterisk (*). The other items are also valuable, and detail can be built up as time and enthusiasm allow.

The Site

Remnant in Farm and Catchment Context*

To allow the management and future planning of the remnant to be integrated into the farm plan, it is important to map the remnant in the context of the total farm and, if practicable, adjoining lands. This will assist multiple use planning, for example: wind breaks/bush corridors, forage shrubs/nutrient filter beds, etc. Steps required are to:

- draw the remnant onto the farm plan
- record the location of other remnants, including shelterbelts and bush corridors (including roadsides) that could be part of the conservation mosaic.

(Note that the Department of Agriculture has recently completed a programme of mapping remnant vegetation. This information can be incorporated into farm planning for individual properties. Contact your local Department of Agriculture office.)

Area and Shape of Remnant*

Small areas are less likely to support viable populations of plants and animals. In addition, the greater the area of the remnant exposed to edge effects such as herbicide drift and weed invasion, the more difficult it is to protect a remnant from degradation. If you divide the boundary length (kilometres) by the remnant area (hectares) and get a figure greater than 0.2, then the remnant will be exposed to a very high level of edge effects. Also, the greater the length of edge, the greater is the expense per hectare of management techniques such as fencing.

The Soil Type and Topographic Features*

It is necessary to note the soil type in order to choose suitable plant species for replanting.

The topographic features are important to clarify the value of the remnant for soil and water management. In addition, special features, such as breakaways, provide habitats for unusual plants and animals.

Map the Remnant

This helps to define features and issues, such as possible erosion hazards, and enables consideration of whether it is useful or feasible to divide the remnant into sections for individual treatment.

The easiest way to produce a map of a remnant is to trace over an air photograph.[1] Apart from rock areas, wetlands, boundaries and tracks, the extent of different vegetation communities can often be easily seen. Figure 4.1 is an example of this sort of map produced by officers in DEC's Wheatbelt Region.

The Plant Community

Map the Plant Communities*

This enables management to be to suited to the different vegetation types. For example, fire management of woodlands and shrublands are likely to differ.

List any Declared Rare Flora*

Declared Rare Flora (DRF) are protected by legislation under the Wildlife Conservation Act (see chapter 5). Mark the DRF on the map of the remnant.

For more information about rare flora, and advice on any specific management requirements, contact your local DEC office. Knowledge of where rare flora grows is of great help to DEC as it provides information for the overall management of these species.

List the Weeds Present*

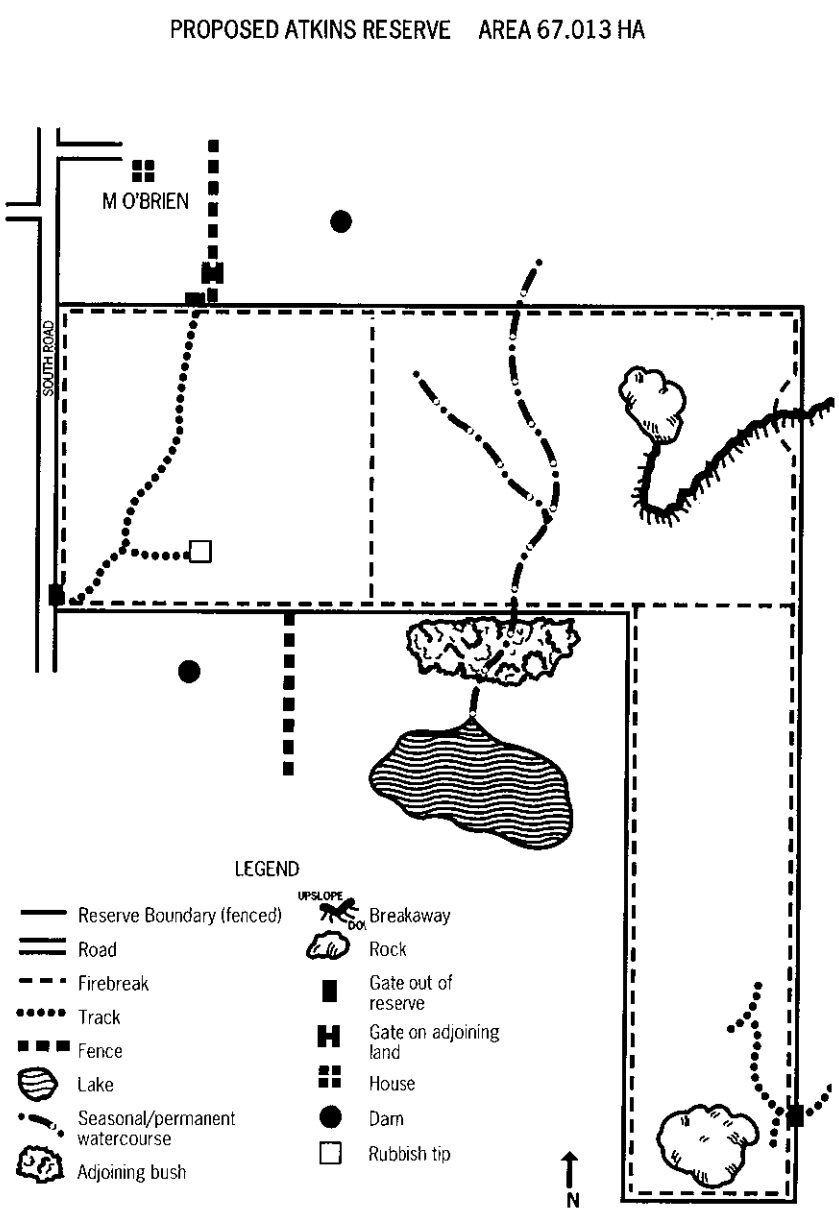
Weeds downgrade the quality of the remnant and may contribute to increased fire hazard. They also hinder regeneration. It is important to record their type and extent, so that correct control measures can be worked out (see chapter 6).

Determine the Health of the Plant Community*

Healthy plants need little management, but unfortunately many rural remnants, especially smaller ones, show signs of stress and rural tree decline (see chapter 5). Specific management may be needed to increase plant health.

Sometimes vegetation health declines gradually over a number of years and is noticed only when it becomes severe. Keeping a photographic record and monitoring every year enables a problem to be detected quickly. It also shows up the positive effects of management as vegetation health improves.

Fig 4.1 Example of remnant map



Considering the main species only, assess the average health of the remnant on the scale in figure 4.2.

All classes of health will occur in normal, healthy plant communities. Furthermore, dead branches are essential for nesting of some birds and other animals. It is a continuing downward change in overall plant community health which would cause concern.

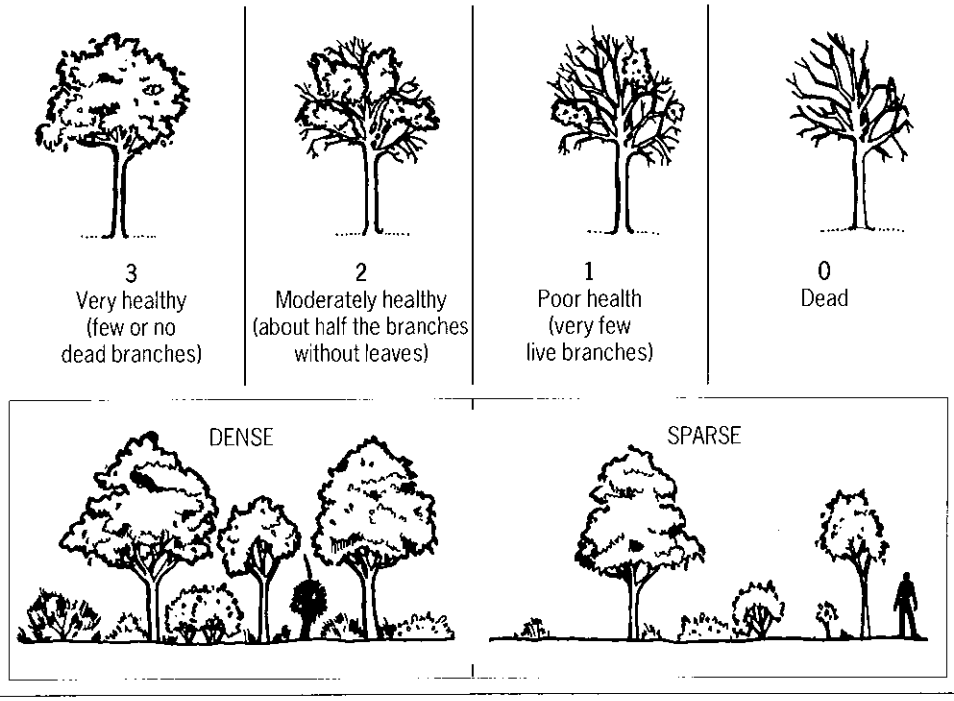
Describe the Plant Community

So that everyone concerned with bush management understands what is meant when a particular type of native vegetation is referred to, a standard method of describing native vegetation has been developed. Use of this standard scheme will help the landholder when seeking information or applying for funding.

The scheme is based on the height of the tallest plant layer and the amount of area covered by the leaves and branches of plants, the canopy cover.[2] A simplified version of the scheme is given in figure 4.4. on page 40. Using it will help landholders to compare their bush with that of other landholders throughout WA.

Vegetation is described according to the height of the tallest plant layer. Most natural areas have several layers; for example, a woodland often has a tree layer, a shrub layer and a layer of small plants such as orchids and everlastings. (But note that mallet and some Goldfields woodlands do not have much understorey.) Scrub, however, may have only two layers, shrub layer and ground layer. The vegetation is described as dense if more than 30 per cent of the available space is occupied by plant canopies and sparse if less than 30 per cent of the available space is occupied by plant canopies (see figure 4.2).

Figure 4.2 Upper: Scale for assessing plant health; Lower: Amount of canopy cover



Above: *A patch of remnant vegetation next to the national park makes a perfect site for the Stirling Range Retreat. Borden.* (G. Sounness)

Above: *Stand of scarlet banksia burnt in 1983. Five thousand stems harvested in 1991, 31 000 in 1992. Wellstead.* (C. Davy)

Above: *The dieback front of the Great Northern Highway road verge north of Muchea. The front is moving away from the camera, where dead banksias can be seen, towards the still-living woodland at the rear.* *(Penny Hussey)*

Above: *Rabbit dung piles provide ideal sites for the establishment of weeds within bushland–here, capeweed in a granite sward.* *(Penny Hussey)*

A vegetation community is given a description by combining the name of the dominant species (this is the most common plant in the tallest layer) with the description based on life form; for example we have jarrah forest, salmon gum woodland, tamma scrub or spinifex grassland.

Prepare a List of Plants

This reveals diversity and any plants for which special management might be needed.

Most native plant communities include a wide variety of different plants and the variety decreases as the remnant becomes degraded. By listing the numbers of different trees, shrubs and ground layer plants, an idea of the quality of the remnant vegetation can be gained. Exciting things can be found too!

It is not necessary to be able to name the plants, though it makes a much more useful and interesting record if you can. For help with plant identification, consult the reference books listed in chapter 11 or contact your local DEC office or local branch of the Wildflower Society or Naturalists' Club. Perhaps best of all, contact a local resident who is known to be interested in wildflowers.

As a land manager, it is important to know the names of plants, to ensure, for example, that the correct species are used for regeneration. However, native plant names can be difficult to remember.

One of the marvellous features of WA's flora is its tremendous variety - no two areas of natural bush are ever likely to contain exactly the same plants. This makes it difficult to keep track of the names, even for a specialist. Once you have managed to work out the name of a plant, it is therefore a good idea to keep a record of it. But the name alone is not much help; it needs to be

Figure 4.3 Use the following table to identify the vegetation community (adapted from B. Muir)[3]

LIFE FORM	CANOPY COVER	
	DENSE (more than 30 % canopy cover)	SPARSE (less than 30 % canopy cover)
Trees - taller than 5 m	Forest	Woodland
Trees - shorter than 5 m	Low Forest	Low Woodland
Mallees	Mallee	Open Mallee
Shrubs - taller than 2 m	Thicket (shrubland)	Scrub (shrubland)
Shrubs - shorter than 2 m	Heath (shrubland)	Open Heath (shrubland)
Grasses	Grassland	Open Grassland
Sedges and Reeds	Sedgeland	Open Sedgeland
Other ground layer plants	Herbland	Open Herbland

attached to a picture of the plant.

A pictorial record can be created in several ways:

- take a colour photo
- make a drawing or painting of the plant
- press a specimen (an old telephone directory is an excellent plant press), then sticky-tape it into a notebook beside its name
- photocopy a specimen (pressed plants photocopy very well, and are easier to keep than the original specimens).

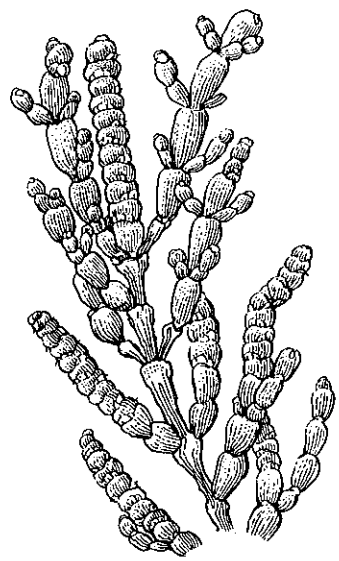
This record could be mounted in the file devoted to that remnant and become a permanent reference picture.

Record Regeneration

Young seedlings of the main plants indicate that the community is capable of regenerating.

Western Australian plant communities often regenerate en masse after an event such as a fire or flood, and so consist of an even-aged stand - flat-topped yates are a classic example. Nevertheless, some seedlings of the dominant plants will usually grow in suitable habitats. This is a very good sign, and shows that the bush still retains its capacity to regenerate.

Record where seedlings occur, for example, track edges or ashbeds, as this could give a good clue for future management.



Find a new species?

Part of a chain of salt lakes was included in a block of land purchased by Alison and John Doley of Coorow. While inspecting the land, Alison noticed that one particular salt lake had an unusual samphire growing around it, which was nothing like the common varieties. In another area grew a dense, low mound plant that looked as though it ought to be a sedge, but produced mulla mulla flowers. She sent specimens of both to the WA Herbarium for identification.

They caused a sensation! The samphire is a new species, never before recorded, now to be named *"Halosarcia koobabbiensis"* after the Doleys' property.[4] The mulla mulla had been recorded once before - by James Drummond in 1840. Its name is *Ptilotus caespitulosus* and it has now been taken off the extinct list.

Even apparently unpromising areas can contain interesting plants. You never know what you've got until you look.

The Animal Community

List the Introduced Animals that Use the Remnant*

Feral animals contribute to the degradation of remnant vegetation. Their numbers should be controlled wherever possible (see chapter 8).

List the Native Animals that Use the Remnant and Observe the Fauna Habitat*

Knowing what animals are present, management can be designed to favour them if desired. By observing what habitats are present, it may be possible to improve the habitat quite simply, for example by adding hollow logs (see chapter 7).

It is much more difficult to assess the native animals present in a remnant than it is to assess the plants. For one thing, plants stay still to let you look at them. In addition, many animals are small, secretive or nocturnal, and unlikely to be seen. Opportunistic observations of fauna should be recorded and specific groups searched for as below.

It may be worth contacting local naturalists and relevant government agencies for advice.

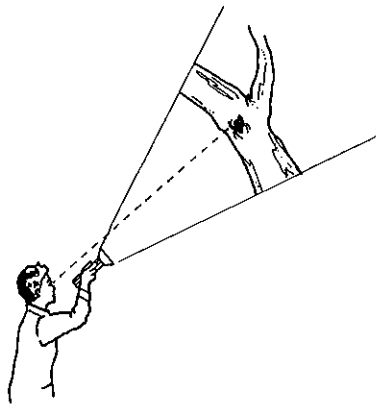
Mammals

As well as actual sightings, note the traces of mammals such as tracks, droppings, diggings, scratches on tree-trunks, etc.

Dusk is a good time to survey for mammals, as many species are active at this time. Spotlight surveys can locate nocturnal animals.

Try to be as quiet as possible so as not to disturb the animals.

Spotlight surveys



Large nocturnal animals such as kangaroos, rabbits and foxes are often observed by spotlighting from a vehicle. Tree dwellers, such as possums and owls, may be seen in this way, too. But vehicles are noisy and restricted to open areas. To get a good idea of the smaller nocturnal fauna, walk for, say, 30 minutes with a powerful spotlight torch. Animals' eyes reflect light, so by looking along the torch beam you will be able to pick out creatures as small as a spider one cm in size from 20 m away!

Spiders' eyes reflect blue-white (so do raindrops, so it is no good doing this on a wet night). Geckos' eyes reflect green, frogs red, birds and mammals usually greenish.

Animals which are likely to be seen by this method include spiders, frogs, geckos, birds such as tawny frogmouth, possums, phascogales, woylies, bandicoots and hopping mice.

Birds

To survey for birds, walk quietly through the remnant for a set period of time, say 15-30 minutes, at different seasons and times of day, noting all birds seen or heard.

With stealth, patience and a good pair of binoculars you are likely to note most of the birds, though remember that there may be different birds present in different seasons. A classic case is the profusion of small birds that will descend on a stand of flowering banksia or dryandra. Spotlight surveys may reveal some night birds, such as owls and nightjars; however, they are more often heard than seen.

For nature conservation, it is more important to encourage a variety of birds rather than a large number of a few species. For example, in one remnant you might count 25 galahs, but nothing else. In another area, 25 birds might be counted, but of 11 different species, including fairy wrens and robins. The second area would be the better bird habitat, as it provides habitat for a greater range of birds.

Darryl Kitchener and his co-workers from the WA Museum have classified wheatbelt birds into those which readily use disturbed areas, and those which are generally only found in undisturbed bush.[5] Birds such as whistlers and fairy wrens have not coped very well with changes to the land and are generally decreasing in numbers; indeed, they may become locally extinct. It is important for remnant management to focus on those species which are dependent on bushland. See figure 4.4.

Other birds such as the galah and little corella, have been favoured by farming and have increased in numbers since clearing. See figure 4.5.

Figure 4.4 Birds which are dependent on remnant native vegetation in the wheatbelt, adapted from Lefroy et al.[6] Those marked "NFS" are not frequently seen and are considered to be of vulnerable status

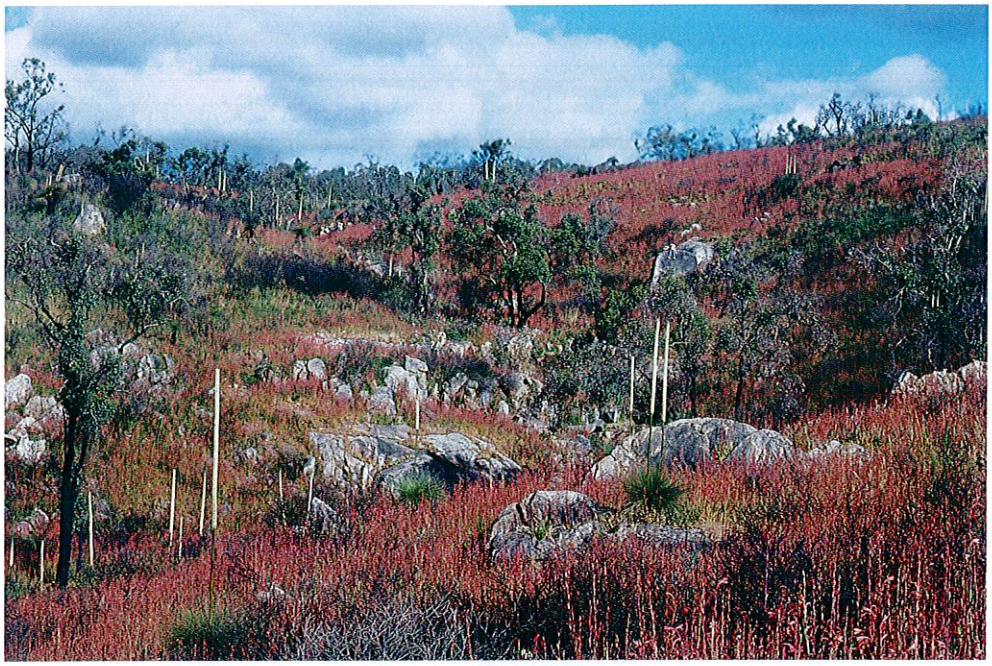
Malleefowl
Painted button-quail (NFS)
Bush stone curlew
Common bronzewing
Carnaby's cockatoo (NFS)
Purple-crowned lorikeet (NFS)
Red-capped parrot (NFS)
Western rosella (NFS)
Smoker (NFS)
Pallid cuckoo
Fan-tailed cuckoo
Boobook owl
Barking owl (NFS)
Tawny frogmouth
Owlet-nightjar
Spotted nightjar (NFS)
White-winged triller
Southern scrub-robin
Red-capped robin
Hooded robin
Western yellow robin
Jacky winter (NFS)
Golden whistler
Rufous whistler
Grey shrike-thrush
Crested bellbird (NFS)
Restless flycatcher (NFS)
Grey fantail
White-browed babbler
Blue-breasted fairy-wren (NFS)
White-winged fairy-wren
Shy hylacola (NFS)
Fieldwren (NFS)
Redthroat (NFS)
Weebill
Western warbler
Inland thornbill
Chestnut-rumped thornbill
Yellow-rumped thornbill
Varied sittella (NFS)
Red wattlebird (NFS in highly cleared areas)
Spiny-cheeked honeyeater
Singing honeyeater
White-eared honeyeater
Yellow-plumed honeyeater (NFS)
Brown-headed honeyeater
Brown honeyeater
White-fronted honeyeater (NFS)
Tawny-crowned honeyeater
Mistletoebird (NFS)
Spotted pardalote (NFS)
Striated pardalote

Two years after a hot summer fire in 1988 (above), prickly moses dominates this Helena Valley scene (top). (Penny Hussey)

A very simple yet effective monitoring technique

- Take photos of the remnant from several recognisable locations. Include any notable features such as a wetland or habitat tree.
- Repeat the photos every year.
- Mount them side by side and note changes.

This is a very effective technique for monitoring whether a management action is working. It shows many things about the remnant, particularly changes in the quality (health) of the vegetation.



Above: *These paired photos were taken in Greenmount National Park, the first in October 1989 after a wildfire had burnt the area in the preceding summer. It shows almost total dominance of the ground layer by the weed* Watsonia meriana. *The second photo was taken three years later in August 1992 and it looks much more 'natural'. The watsonia is still there but it is part-hidden by shrub regrowth, notably of the fire-stimulated seeder, prickly moses* (Acacia pulchella). *Appearances can be deceptive! If possible, try to control major weeds such as watsonia when it has only a small population because, when it reaches this extent, control becomes impossible - containment is the only option.*

Reptiles

Many reptiles may be observed basking in the sun during the day on rocks or logs. Yet others may be observed in shelter such as under rock slabs, in crevices in bark or inside hollow logs. (If you turn over a rock looking for creatures, remember to replace it in its original position.) Take great care when investigating these places for reptiles as you might come across a snake who could be annoyed at being disturbed!

The only reptiles likely to be seen on a spotlight survey are the nocturnal geckos.

Frogs

Frogs are most usually recognised by their calls. Even if they cannot be named, the variety of species calling can easily be established. Different types of tadpoles are also easily seen.

A diversity of frog species indicates that the water on a remnant is in a reasonably natural condition. Many frogs cannot survive increased salinity. A comparatively easy way to find out how many frogs are in a remnant is to count the number of different frog calls. This alone will show the diversity of frogs in a remnant if done over a full year. Figure 4.6 provides further information which will enable more common species to be identified on call alone.

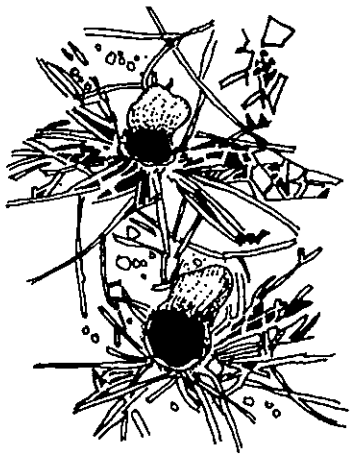
Figure 4.5 Increaser species - birds which have benefited from agricultural development, adapted from Lefroy et al.[7]

Crested pigeon
Galah
Stubble quail
Banded plover
Black-faced cuckoo-shrike
Pied butcherbird
Australian magpie lark
Little crow
Australian magpie
Straw-necked ibis
White-faced heron

Invertebrates

Invertebrates are an essential part of the bushland ecosystem, but they are often ignored in assessments as there are so many different kinds and they are so difficult to identify. Invertebrates such as ants, termites, various other burrowing insects, centipedes, scorpions and spiders all play an important role in soil tilth, water percolation and nutrient cycling.

Because they are predators at the top of the invertebrate food chain, an abundance of spider species indicates that a wide range of food animals - mostly insects and other invertebrates - are present. Thus spiders are a good indicator of the general health of a community.[9]



Trapdoor spiders' burrows

Trapdoor spiders are large, sedentary and at the top of the invertebrate food web, and their distinctive burrow entrances are relatively easy to find, once you know what you are looking for. A diversity of these and other large spiders are an indication of remnant health. Some of the distinctive burrow entrances of trapdoor spiders are shown above and in figure 4.7.

Figure 4.6 Male breeding call, calling position and season for more widespread south-western frogs. Adapted from Main[8]

SPECIES	CALL	CALLING POSITION	REMARKS
SUMMER (Dec-March)			
Neobatrachus kunapalari	short high-pitched trill	floating in shallow temporary ponds which fill after summer cyclonic rains & thunderstorms	also calls during autumn and winter if nights are warm; northern and eastern wheatbelt
Pseudophryne occidentalis	rather variable, long squelch to short chick	in shallow burrows; in moist clay by temporary ponds of cyclonic rains & thunderstorms	sometimes calls during autumn if nights are warm; eastern wheatbelt & Goldfields
AUTUMN (April-May)			
Heleioporus eyrei	a long, low moan, slowly repeated	burrow in sites of temporary swamps, before they fill	calling period very restricted; West and South Coastal
Heleioporus albopunctatus	short, high-pitched calls, slowly repeated; "coo coo"	as for H. eyrei	agricultural areas except extreme south-west
Pseudophryne guentheri	a short grating call: "ka-a-ak," slowly repeated	under litter in shallow burrows in swampy country, before watertable rises	widespread in the South-West
Neobatrachus pelobatoides	a long, soft, purring trill, slowly repeated	floating in temporary ponds	may call in early winter if warm. Agricultural areas except extreme South-West and South Coast
WINTER (June-August)			
Crinia pseud-insignifera	series of 4-pulsed "bleats"	floating in temporary ponds, or sitting in shallow water at edges	wheatbelt and to the edge of the Darling Scarp
Crinia georgiana	a variable duck-like "quack-quack"	sitting in shallow, temporary hillside streams and some of the streams on the coastal plain	wetter South-West
Limnodynastes dorsalis	a banjo-like "plonking" call	floating in temporary or permanent water	calls occasionally heard throughout year. Widespread in South-West
Litoria adelaidensis	grating call: "ka-ark", may end in a high-pitched shriek	out of water from reeds and rushes in permanent lakes and swamps	some calls heard through year. Wetter South-West and western edge of wheatbelt.
SPRING (September-November)			
Litoria moorei	a long, low growl usually followed by 3-5 distinct grunts	floating or on floating vegetation in permanent swamps and lakes	wetter South-West and western edge of wheatbelt.

Incidentally, trapdoor spiders are one of the first species to be eliminated when a bushland remnant is grazed by stock.

Insects which are restricted to native vegetation, according to Terry Houston from the WA Museum, are assassin bugs and robber flies (see figure 4.7). Any remnant on which these animals are found is likely to be in good condition.

The History

Knowledge of past management may help to understand the current appearance of the site.

List the Fire History*

Activities listed should include all that is known, especially time since the last burn. This will be valuable in deciding upon regeneration techniques (see chapter 9).

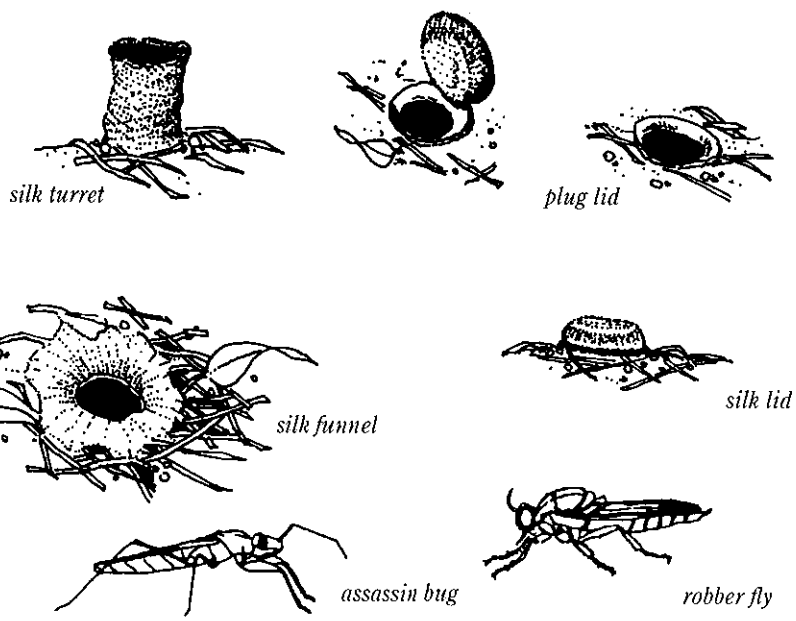
Other useful information includes how intense or hot the last fire was and what sections of the remnant were burnt. It may be possible to compare burnt and unburnt sections to guide future fire management.

List the Human Usage*

Activities listed could include grazing, logging, gravel mining and rubbish disposal.

Some activities have a lasting effect on remnant vegetation and may require specific rehabilitation (see chapter 10).

Figure 4.7 Trapdoor spider burrows and other invertebrates of undisturbed bush



5 Principles of Native Flora Management

- Role of plants
- The plant community
- Natural disasters - succession
- The effect of grazing
- Legal aspects
- Causes of rural tree and shrub decline

Note also

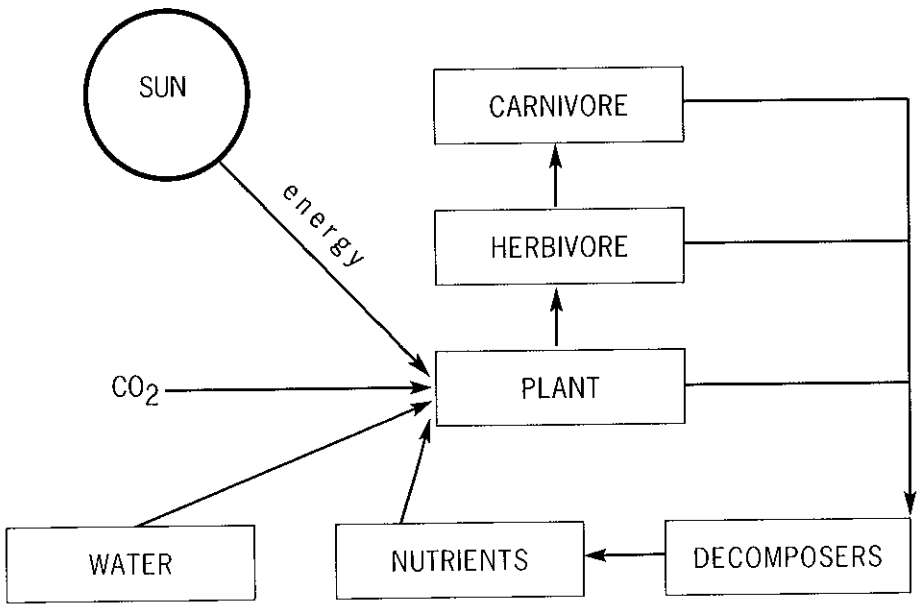
Problem plants: Chapter 8
Fire and plants: Chapter 9
(parts of chapter only)

Role of Plants

The Food Web and Exchange of Gases

Green plants are the foundation of most living communities. Without green plants, there would be no animals. Plants take water and nutrients from the soil, carbon dioxide from the air and, with the help of sunlight, manufacture sugars (carbohydrates) in the process called photosynthesis. These carbohydrates are then used for energy to build up all the other materials needed by the plant. Animals cannot make their own food; instead they consume plants (herbivores), other animals (carnivores) or both (omnivores). Decomposers, such as

Figure 5.1 Part of the carbon cycle



bacteria and fungi, break down the dead remains and release the nutrients back into the system.

A by-product of photosynthesis is oxygen, needed by most living things to convert sugars for energy (aerobic respiration). As life evolved on earth, the oxygen released by early photosynthetic organisms - blue-green bacteria - slowly built up until there was sufficient free oxygen to enable aerobic respiration to evolve. Previously, all respiration was anaerobic (without oxygen), as still occurs in some bacteria - for example the sulphur bacteria which decompose seaweed and produce an unpleasant smell like bad eggs. This stage took about 2000 million years and led to the evolution of animals and all other plants. So far photosynthesis has raised the atmosphere's free oxygen level from 0 per cent to 21 per cent.

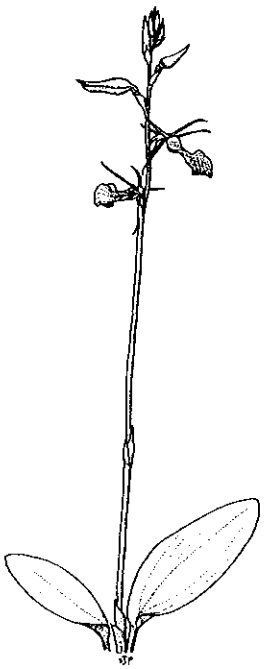
At high altitudes oxygen reacts to form a layer of ozone around the Earth. This is very important as it absorbs the sun's dangerous ultra-violet radiation, and there seems little doubt that it was the formation of this layer which enabled life to evolve beyond the bacteria stage.

These relationships between plants, animals and their environment are delicately balanced and alterations may lead to change in the species which can live in an area - a change in the species composition.

Interactions with Animals

Not only are green plants vital as the basic energy producers on earth; they also provide shelter and suitable habitat for animal life. Vegetation provides nesting sites and respite from the extremes of the weather. Large old habitat trees have been called nature's boarding house because of the number of different living spaces they offer to a variety of creatures.

Other and more complex interactions



Sex appeal and the slipper orchid[1]

The slipper orchid (*Cryptostylis ovata*) grows in the wetter regions of the south-west, from Perth to Hopetoun. It is a stout plant which produces its inconspicuous brown flowers in summer. The flowers give off a scent, similar to that of the female wasp, which attracts male ichneumon wasps (*Lissopimpla semipunctata*). A wasp backs into the flower, attempting to copulate with it as though it were a female - semen is actually deposited in the flower. During this process, pollen gets stuck to the wasp's rear end and transferred to another flower when he is duped again.

Without the ichneumon wasp, the slipper orchid could not set seed and would eventually become extinct.

also exist. Many plants depend on animals for pollination or dispersal of seed, and some of these relationships are bizarre, such as that between some orchids and the wasps which pollinate them.

Plants and the Soil

Healthy soil is the foundation for healthy vegetation, and plants play a significant role in soil development.

Nutrient Cycling

Plants obtain water and nutrients from the soil. The quantity of available water depends on climatic factors, soil structure, soil type and drainage. Soil nutrients, including phosphorus, potassium and trace elements, are principally derived from two sources, as direct breakdown from the parent rock or as by-products of the decomposition of plant and animal remains.

Breakdown of parent rock to form young soils is increased following periods of geological activity such as mountain-building, volcanism and glaciation. Because it is many millions of years since these forces have been active in WA, a very stable and geologically ancient region, many of the nutrients have already been removed, leaving nutrient-poor soils. Most of the available nutrients are tied up in the tissues of the plant community, and require decomposition on site to be returned to the soil.

Dead leaves, twigs and bark, together with native animal droppings, fall to the ground where they are called leaf or soil litter. The activity of fungi, bacteria and invertebrates such as termites gradually decomposes this litter into humus and releases the nutrients contained in it back into the soil for plant use. In drier environments, this decomposition can be very slow, but it is nevertheless vital for the long-term health of the plant community. If plant material is removed from a community, for example by reaping a crop, then the soil nutrient store will become depleted and the subsequent plant growth will be poorer until the nutrients have been replaced in some way.

Fire is a special case. When organic material is burnt, carbon and nitrogen are lost to the atmosphere, but other minerals, such as potassium, phosphorus, cobalt or magnesium, remain in the ash. These are immediately available for plant use and provide for the flush of growth which occurs soon after fire. The nitrogen, however, is still low, and has to be built up again.

Nitrogen is a vital plant and animal nutrient, as it is an essential constituent of protein, but although it makes up 78 per cent of the atmosphere, most plants cannot use it in this form. Some bacteria and blue-green bacteria (which are sometimes mistakenly called blue-green algae) can fix this atmospheric nitrogen into a form plants can use. These organisms are free-living within soil and water, but they also occur in association with the roots of certain plants.

Plants of the pea family have nodules on their roots in which nitrogen-fixing bacteria form colonies. Surplus nitrate made by the bacteria is available for the plant, which consequently grows well even in nitrogen-poor soils and has a high protein level in its foliage and seeds. When these plants die, the nitrate in their tissues decomposes into the soil. This is, of course, the principle behind having clover, lupins or peas in a paddock rotation. Native plants from this group - peas, wattles and cassias - contribute nitrogen to the bush ecosystem in this way, as do sheoaks.

Blue-green bacteria are very important in contributing usable nitrogen to harsh environments. The black layer on granite rocks in the jarrah forest, for example, is a blue-green bacterium called *Calothrix*. As it dies and decomposes it is washed or blown into the rock pools and moss swards, where it provides essential nutrient for the growth of other plants. In the semi-arid woodlands

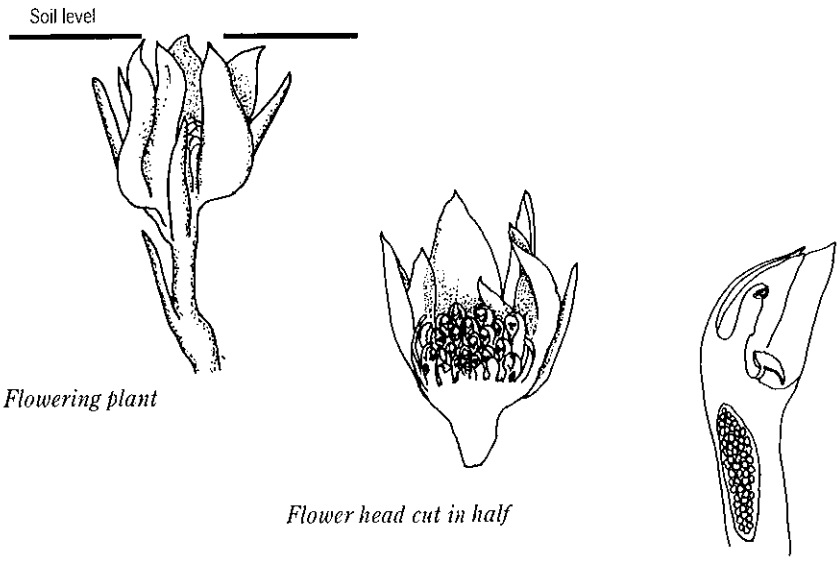
and mulga belt, crusts of blue-greens form on the surface soil, absorbing water, preventing erosion and, eventually, contributing nitrogen for use by other plants. Blue-greens also live in the roots of plants such as zamia (*Macrozamia reidlei*) and contribute nitrogen for their growth. These plants are also important in bush nutrient cycling.

Many plants have beneficial interactions between their roots and soil fungi. The fungi grow on the outside of the root, or within the roots themselves, and are called mycorrhiza. Evidence is accumulating that these interactions are vital for the survival of many native plants.[2] All eucalypts have their fungal partners but more extreme examples are provided by the bell orchid (*Gastrodia sesamoides*) and the underground orchid (*Rhizanthella gardneri*) which contain no chlorophyll at all and obtain their nutrients entirely from the waste products of associated fungi.

The underground orchid is an extraordinary plant which has no green leaves and exists almost entirely beneath the soil, drawing its nourishment from associated mycorrhizal fungi which in turn feed on living broombush (*Melaleuca uncinata*). In May/June the orchid pushes a flowering stem up to the soil surface to allow midges and other insects in for pollination.[3]

A rather more spectacular way of getting extra nitrogen is provided by insectivorous plants, which catch and digest insects. Western Australia has many beautiful sundews (*Drosera* spp.) and also the rainbow plant (*Byblis* spp.) which all catch insects on sticky leaves. Tiny, but often very pretty, bladderworts (*Utricularia* spp.) trap water fleas in swamp water, while in dense swamp vegetation on the south coast the unusual Albany pitcher plant (*Cephalotus follicularis*) traps ants and midges in leaves shaped like a jug.

Figure 5.2 Underground orchid Rhizanthella gardneri



The banksia family (Proteaceae) has developed an extraordinary adaptation to living in our nutrient-poor soils. These plants have a very specialised root system, proteoid roots, which grow in the upper layer of the soil and among the leaf litter itself. These hairy rootlets probably speed up nutrient absorption by sticking directly to the leaf litter and actively promoting nutrient release. Thus banksias and their relatives are able to grow well in nutrient-poor soils.

This ability has a negative aspect, though, in that too much fertiliser can kill them. Because they are so efficient, especially in absorbing phosphorus, heavy fertiliser application causes them to absorb too much nutrient and poison themselves.[4] This effect can be observed happening to banksias in paddock shelter-belts - for example on the Esperance sandplains - where superphosphate drift causes initial spectacular growth, then sudden collapse and death.[5]

Soil Stabilisation

Vegetation cover protects the soil and minimises soil particle movements by wind or water.

Plant roots assist with the penetration of the soil by air and water and may also contribute to the breakdown of the underlying rock substrate.

Plants and Hydrology

The contribution of remnant vegetation in the management of surface and groundwater flows, lowering the watertable and preventing salinity, is discussed in chapter 2.

Plants and Climate

Atmospheric Moisture

Plants can affect the climate, though scientists differ in deciding how much of an effect they have. Through transpiration (water loss) from their leaves they put moisture into the atmosphere. This contributes to atmospheric humidity and may have an effect upon rainfall, although it would probably be small in an arid climate such as in WA. The increase in humidity is, however, very important beneath the tree or shrub canopy, as it permits the survival of small delicate plants or animals prone to drying out.

The Greenhouse Effect

Recently, the role of plants in removing carbon dioxide from the atmosphere to slow down the so-called "Greenhouse Effect" has received attention in the media. Photosynthesis converts carbon dioxide into carbohydrates which are then converted into other substances making up the bulk of the plant or animal. Thus the carbon dioxide is removed from the atmosphere until decomposition or a fire releases it once more. In the past, huge amounts of carbon dioxide have been taken out of the atmosphere by living organisms in this way, to be stored in the earth as oil, coal, peat or limestone. Since the industrial revolution, however, we have been burning the fossil fuels faster than nature can reform them, and so the amount of carbon dioxide in the atmosphere is building up.[6] See figure 5.3 on the next page.

Since the carbon dioxide acts like a blanket, keeping heat from escaping from the Earth into space, it follows that the Earth must be heating up. Global temperature measurements taken over the last century seem to support this - NASA states that six of the seven warmest years in over 100 years occurred in the 1980s, and the hottest was 1990.[7] There is considerable debate as to whether this is merely a cycle which will swing the other way, or whether it is a permanent trend. Without a crystal ball, no-one can say for sure!

The likely results of the Greenhouse Effect are beyond the scope of this book, but it should be noted that rapidly-growing perennial vegetation, as opposed to

seasonally-growing annual vegetation, will soak up more carbon dioxide. (To have an effect globally, a huge quantity of trees would be needed - but every little bit helps. As the slogan reminds us: "Think globally: Act locally".)

The Albedo Effect

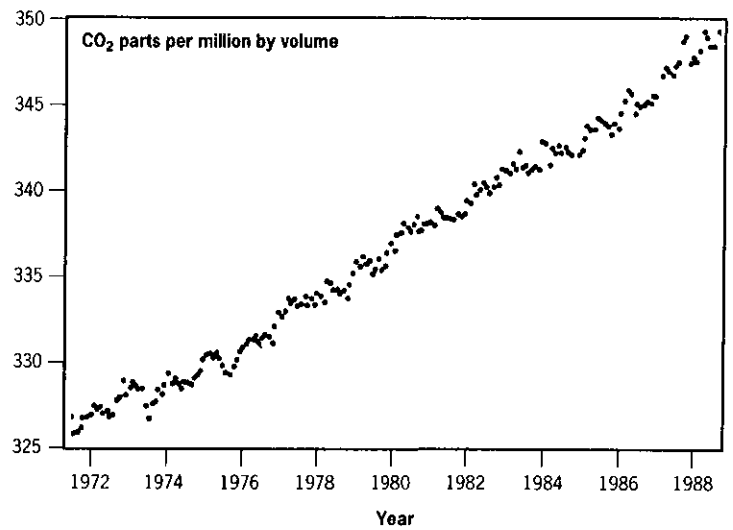
Another effect that is poorly understood involves the way solar radiation is reflected from the Earth (the Albedo Effect). Bare soil and light coloured pasture or crop (i.e. in summer, when dead and dried yellow) reflect more than growing vegetation and thus have a higher albedo, and a multi-layered perennial vegetation community such as a forest reflects the least, and therefore has a low albedo. Other situations which produce a high albedo effect are dense cloud cover and an increase in ocean microflora. High albedo has a cooling effect on the atmosphere and leads to unusual fluctuations in rainfall, complicating any attempt at predicting climate change.

The Plant Community

A natural vegetation community is the characteristic group of plants which grow naturally together in a particular place. The composition of this community is determined by a complex interaction between factors such as climate, soil, grazing, and position in the landscape. At the local scale, botanical consultant Ted Griffin has shown for the Dandaragan area that the most important factors that control where plants will grow are the soil type and underlying geology.[8]

This is true of other areas in WA. Much of the WA wheatbelt is a repetitive sequence of gravelly or sandy uplands, often with heath, scrub or mallee vegetation; valley slopes with red soils supporting a woodland; and valley flats with saline grey soils that would

Figure 5.3 Atmospheric carbon dioxide concentrations over south-east Australia for the years 1972 to 1988



originally have carried a mixed woodland and saltbush community. At any point in the sequence, granite outcrops can occur.[9]

Subtle variations in soil type, moisture holding capacity, slope, time since the last fire, attack by disease, or any one of dozens of other factors, lead to a mosaic of different vegetation associations keyed to minor changes in the landscape. For example, the "typical jarrah forest" could be thought of as forest on gravelly soils, but in fact it is a mosaic of dense streamside vegetation, swamps, sandy areas, breakaways and rock outcrops all with their different characteristic vegetation communities.

This all makes it likely that no two patches of remnant vegetation are exactly alike. Although the dominant plants may be similar, each remnant may well contain a different assemblage of shrubs or ground layer plants, and the further apart they are, the more likely this is to occur.

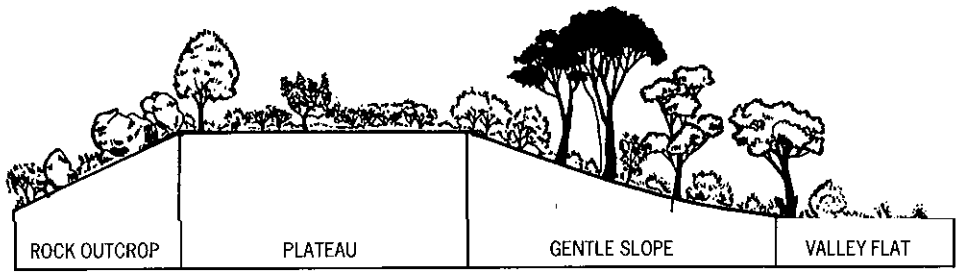
So all remnants are likely to be valuable for the conservation of native plant communities.

Natural Disasters - Succession

Australian vegetation is accustomed to surviving natural disasters. For millions of years droughts, fires, floods, cyclones, pests and diseases have caused the death of mature plants, yet the vegetation community has regenerated vigorously. This regeneration follows a pattern called succession.

For example, in the first year following a fire, annuals and short-lived perennials carpet the ground but these are reduced in later years by the regrowing shrubs and trees. The seeds of these plants remain stored in the soil until a future disturbance again triggers their germination. Just because a plant is not visible, it does not

Figure 5.4 The main native plant communities of the northern wheatbelt, WA. The low rolling hills typically rise less than 30 m above the valley flats



SOIL					
Thin and stony	Yellow sand over laterite		Red loam		Saline grey soils
PLANT COMMUNITY					
Moss Sward: thickets on run-off areas	Heath/scrub Mallee	Woodland			Thicket Samphire marsh
COMMON PLANTS					
Rock oak Boryas Hakeas Wattles Orchids	Grevilleas Verticordias Mallalie Mottlecah	Tamma Hakeas Wattles	Everlastings Jam Salmon gum Broombush	York gum Red morrel Daisy bush	Melaleucas Samphire Cord rush York gum Jam

necessarily follow that it has been lost. On Middle Island off the south coast there is evidence that some plants have persisted as soil-stored seed for 170 years![10]

Perennial plants survive disasters in two ways, either by growing from seed or by sprouting from a persistent rootstock. Some plants concentrate on only one of these strategies - for example, showy banksia (*Banksia speciosa*) which is common on Esperance sandplains, regenerates only from seed which is stored in cones on the bush. Many other plants, including most mallees, regenerate principally from their mallee root. For regeneration of a natural community to proceed normally, either seeds or rootstocks of all the constituent plants must be available at the site.

During a natural succession after a disturbance, it often happens that some shrubs, such as wattles, grow very quickly and dominate the scene for a few years, but they are short-lived and are replaced by the slower-growing, longer-lived species. Thus the community changes in appearance with time since the last disturbance. This changing structure of the vegetation community provides different habitat for animals. Not all fauna can utilise every stage of the succession. Ground parrots and noisy scrub-birds, for example, need long-undisturbed vegetation for their survival, while kangaroos are attracted to the fresh regenerating shoots after a recent fire, avoiding old growth except for shelter.

Although a natural disturbance can seem to be a disaster when it occurs, some plants benefit from these occasional events and established a new generation.

Because of their isolation, the effect of disasters on remnants will be more extreme than on large areas of bush, so any man-made intervention, such as a deliberately-lit fire, should be carefully thought out before it is undertaken (see chapter 9).

The Effect of Grazing

Prior to European settlement there were very few large herbivorous animals in Australia. The large grazers of the Aboriginal Dreamtime had all become extinct and, unlike other continents, the grasslands of Australia had no herds of hoofed mammals. The biggest kangaroos, though plentiful in some areas, depend upon fresh drinking water or green herbage, and this limits their range, although, like most other fauna, they move around the countryside in response to the availability of water and food.

Europeans introduced hoofed mammals and rabbits, provided water for them to drink and in many places confined them by fences into particular areas. This produced an increase in grazing and browsing pressure, combined with soil damage by hooves, which in many areas has resulted in severe degradation of native vegetation and also severe land degradation.

It is important to point out that any heavy grazing pressure will damage natural bush, whether those grazers be sheep, goats, rabbits, locusts or kangaroos, but the speed of degradation and the effects are different for each animal. Under natural circumstances, native vegetation has evolved strategies to cope with grazing pressure from kangaroos, which take small, neat bites; it is the introduced animals that cause the greatest problems.

There is no doubt that grazing by stock leads to degradation of remnant vegetation. The heavier the grazing pressure, the smaller the remnant and the drier the climate, the faster the degradation is likely to occur.

If remnant vegetation is to persist into the future, then grazing by stock should be excluded.

Effects of Grazing Pressure

All the effects of grazing pressure occur under light stocking rates as well as under heavy stocking; they are just slower to appear. Between light and heavy stocking, the effects are largely a matter of degree.

Selective Elimination of Palatable Species

Palatable ground layer plants, including regenerating seedlings, quickly disappear from the community, followed by all palatable shrub foliage within reach. A noticeable browse line is developed. Bark may be chewed and even sizeable trees ringbarked. The community becomes one of aging shrubs and trees which will eventually die out if grazing is continued.

This loss of seedlings and regenerative ability is most important after a major disturbance, or when rehabilitation of the native vegetation is desired.

Sandalwood is particularly vulnerable to grazing pressure, and in places where the grazing pressure is heavy, young sandalwood will only be found when protected, for example by growing within prickly acacias like kurara (*Acacia tetragonophylla*).

This effect is well known in the pastoral regions. In fact rangeland managers talk of the percentage of decreaser species (the plants sheep like to eat) versus increaser species (the plants sheep don't like to eat) as an indicator of rangeland condition.[12]

Physical Plant Damage

All large browsers can cause mechanical damage as they reach up into shrubs and trees for edible morsels. Goats are notorious for this, but, when desperate, sheep will also scramble up as high as they can get. Cattle, being large and heavy, cause such damage quite quickly.

The effect of domestic stock on remnant woodland[11]

Anne Scougall and Jonathan Majer of Curtin University studied the effects of stock having access to woodland remnants of York gum and jam, north of Kellerberrin. Three of the remnants are fenced reserves, from which stock have been excluded; the other four are not fenced and are open to stock during the typical three-year wheat/sheep rotation. In all cases the study sites were on a north-facing edge between a paddock and the treed remnant.

For each remnant they studied 23 different factors - from tree height, to soil acidity, to how rapidly ants removed jam seeds - then they compared the results from the fenced and unfenced remnants. In all cases there was a difference between the two types of site, pointing to a degradation of the remnant vegetation where stock have been permitted access.

Some of their results are shown on the next page.

This work shows that stock cause detrimental changes to the soil, plant and animal characteristics of remnant vegetation.

The study concludes: "Remnants of native vegetation which are subject to the additional impacts of livestock intrusion are set on a path to destruction and their loss from the landscape in the longer term is inevitable."

FACTOR	CHANGE IN UNFENCED REMNANTS COMPARED WITH FENCED REMNANTS	CAUSE OF CHANGE
soil compaction	higher	stock trampling
amount of mineral nutrients	higher	stock droppings
phosphorus	same	little fertiliser drift
soil pH	more acid	ammonium from droppings acidifies the soil
soil moisture	higher	a) fewer plants = less water use b) more compacted soil = more water retention
soil salts	higher	moist soils = mobilisation of stored soil salts
number of dead trees	higher	browsing damages plants
amount of soil litter	lower	fewer plants = less litter
number of individual plants	lower	grazing removes some plants and prevents seedlings from establishing
number of different types of plants	lower	grazing removes some plants
tree height	same, except taller at paddock boundary	fewer plants = reduced competition by remaining trees for nutrients
weed invasion	higher	a) stock transport weed seeds in manure and on their bodies b) fewer plants = easier for wind to blow seeds in c) increased soil nutrients + soil disturbance = better weed growth
numbers of individual ants	higher	change in soil structure + food availability = change in ant fauna
types of ants present	changed	a) less shade = more heat-loving, fast-moving ants b) more compacted soil + less soil litter = less soil and litter ants
seed dispersal patterns	changed	fewer ants preferring native vegetation = less dispersal of jam seed

Hoofed animals trample and destroy small plants, especially those with a mat habit, such as the pincushions (*Borya* spp.) which grow on rock outcrops.

As well as eating leaves and stems, rabbits eat roots and chew through them when digging a burrow, thus causing stress and sometimes killing plants.

Ringbarking

Animals can chew bark and so ringbark trees and shrubs. Rabbits tend to do it in summer, when other food is scarce, sheep in autumn when there is little fibre in paddock feed. Rams rub and butt up against the trees and can cause ringbarking in that way. Cattle, particularly bulls, also do this.

Horses are notorious killers of paddock trees. They chew bark out of boredom, or because they like the taste. Three horses in a paddock near Byford took 36 hours to totally consume a three metre high WA Christmas Tree *(Nuytsia floribunda)* - to the consternation of their owner when she arrived with wire to protect it![13]

Consumption of Leaf Litter

During times of low food availability, rabbits and sheep will consume the leaf litter which accumulates under shrubs. Not only does this interrupt the nutrient cycle, it exposes the soil to the heat of the sun, damaging roots and increasing water loss. Plant growth is inhibited as most plants, even in arid regions, prefer a cool root run.

Effect on Soil Bacterial and Lichen Crusts

In undisturbed natural communities in drier areas, the soil surface carries a crust of lichens and blue-green bacteria. These crusts hold the soil in place during the summer dry period, hindering wind or water erosion; they assist with water infiltration and play a vital part in the soil nutrient cycle.[14] The blue-green bacteria are nitrogen-fixing. They grow rapidly with the first rains and, when they decompose, produce nutrients for both annual and perennial plants.

Stock hooves break up this surface crust, disrupting the nutrient cycle and leaving the soil open to wind and water erosion. In addition, without the crust the soil is less wettable, so water penetration is decreased, and run-off increased.

Soil Compaction

Stock follow trails and their hooves compact the soil, leading to decreased infiltration and increased run-off.

The stock pad is often the focus for wind and water erosion to commence and the erosion can spread outwards on all sides.

Altered Patterns of Run-off

Run-off is channelled along a stock pad and, if it traverses a slope on which sheet flow is important, downslope areas of water starvation can occur. Roads and tracks can also cause this problem.

Additional Nutrients

Animal excreta add nutrients to the soil. Most WA soils are naturally nutrient-poor and the plants are adapted to cope with this. Where stock camp in a remnant and around rabbit dung piles, nutrient levels can rise dramatically. This will be beneficial to some plants in the natural community but may be detrimental to others, for example banksias.

Trees growing in soils with high nutrient levels may be subject to more severe attack by defoliating insects than trees growing in poorer soils (see page 73).

Introduction of Weeds

Stock bring in weed seeds, either internally, such as when wild oats (*Avena fatua*) germinate in horse droppings, or externally, like corkscrew (*Erodium botrys*) or double-gee (*Emex australis*) seeds caught on a sheep's coat and brushed off as it passes among shrubs.

This is an important method of weed introduction into native vegetation. When combined with soil disturbance created by hooves and raised nutrient level from droppings, both of which favour weed growth, it leads to loss of the native ground layer and degradation of the remnant.

Management of Grazing

All remnants should be enclosed in a stock-proof fence. There are several reasonably cheap yet satisfactory configurations available. To cut costs still further, living trees may be used as temporary strainer posts, although this should be avoided if possible.

It is possible that financial help for fence construction may be available from government funding bodies.

An attempt should be made to control rabbits in remnants (see chapter 8).

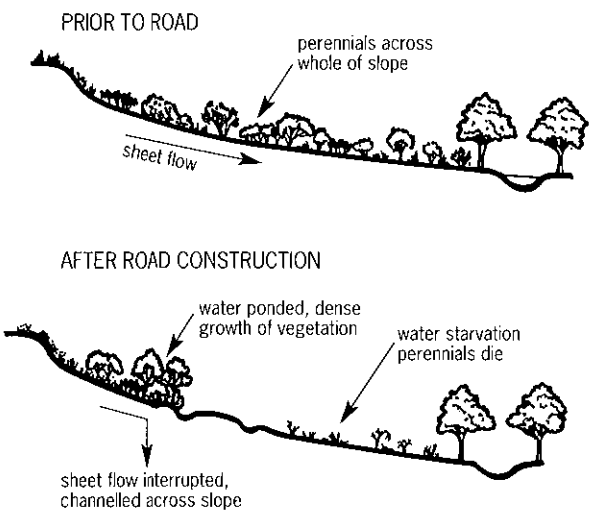
Under what Circumstances Can Remnant Vegetation be Grazed?

Remnants can be classified into four categories, depending on the quality and diversity of the vegetation which remains in them (see chapter 4).

- **Top quality vegetation** should never be grazed, as such grazing will degrade it. However, in a dire emergency, it could be used as shelter during an extreme weather event, provided the stock are taken out again immediately afterwards.
- **Good quality vegetation** could be subject to an occasional short-duration light stocking in times of emergency, but each such event will cause an elimination of any regeneration and a general degradation of the community. It should be followed by a sufficient time to permit regeneration and regrowth. This will vary according to the climate and has been

Death of mulga along the Great Northern Highway

In many areas of the north-west, run-off occurs as sheet flow, rather than in distinct channels. Road construction may interrupt this flow, ponding water on the upslope side and causing water starvation and death of perennial vegetation downslope.[15]



North of Meekatharra, there are areas where mulga deaths have occurred up to a kilometre from the road, and the effect is still spreading.

The new section of the highway north of Newman has been designed to alleviate this effect, with frequent culverts and level sill absorption banks on the downslope side.[16]

little studied, but is unlikely to be less than two years.

- **Moderate quality vegetation** has often got that way because of grazing pressure in the past. If the area is not to continue to degrade, grazing management must be practised. If it is considered essential that stock have access to the area, then fencing it into sections could be considered. This would allow rotational grazing, with each area given as long as possible for recovery and regeneration. If there are several moderate quality remnants on the property, they could be fenced and incorporated into a rotational grazing scheme.
- **Poor quality vegetation** may have a grazing regime built into the management plan, for example to control exotic grasses and so reduce fire risk, but it should take into account the time needed for any planted or regenerated trees and shrubs to grow sufficiently to withstand grazing pressure. For sheoaks and palatable wattles, for example, the growing tips should be out of the reach of stock. Alternatively, special protection, for example fencing, could be given to the seedling areas.

Legal Aspects

In WA, all naturally-growing native flora are protected under the Wildlife Conservation Act, administered by DEC. Under the provisions of this Act, DEC issues licences to take flora for either scientific or commercial purposes on Crown Land, and where flora is taken for sale off private land. This applies to flowers, seed and other parts of the plants. In forest areas, some flora is considered to be forest produce and licences to harvest it are issued under the provisions of the Conservation and Land Management Act. Contact a DEC office for details. Except for those areas where Declared Rare Flora exist (see below), the Wildlife Conservation Act does not affect clearing of private land unless it is proposed to sell protected plants.

However, for clearing of native vegetation on private land the Commissioner of Soil and Land Conservation (Department of Agriculture) must be notified at least 90 days before clearing begins. This allows the Commissioner to assess the land for potential land degradation hazards, and to protect areas where required for land conservation. Farmers in catchments controlled by the Water Authority of WA are legally required to obtain a licence from the Water Authority to clear native vegetation.

Declared Rare Flora

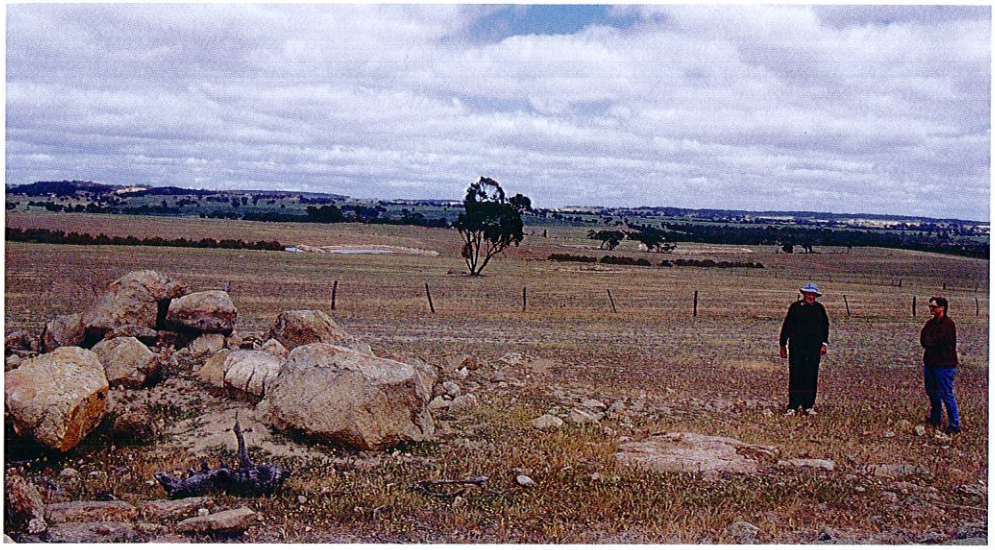
Plants which are rare, or considered likely to become extinct or otherwise in need of special protection, may be gazetted as Declared Rare Flora by the Minister for the Environment under the Wildlife Conservation Act.[17] No-one is allowed to take (pick or damage) these plants without a specific authorisation from the Minister. Contact a DEC office for details.

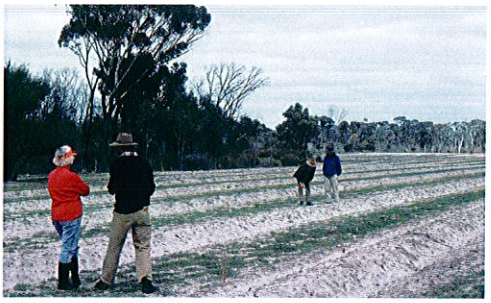
Priority Species

DEC also maintains a Priority Flora List of species that require further survey or monitoring to determine their conservation status. The Declared Rare and Priority Flora lists represent those species of particular conservation interest in WA.

Causes of Rural Tree and Shrub Decline

In many rural areas the conspicuous elements of the natural vegetation - trees - are dying. Bill White of Williams, for example, estimates that he is losing between three and five per cent of his property's tree cover per year. Although now well treed, he believes that unless something is done, within 30 years there will not be a single live tree left on the property. This gradual loss of



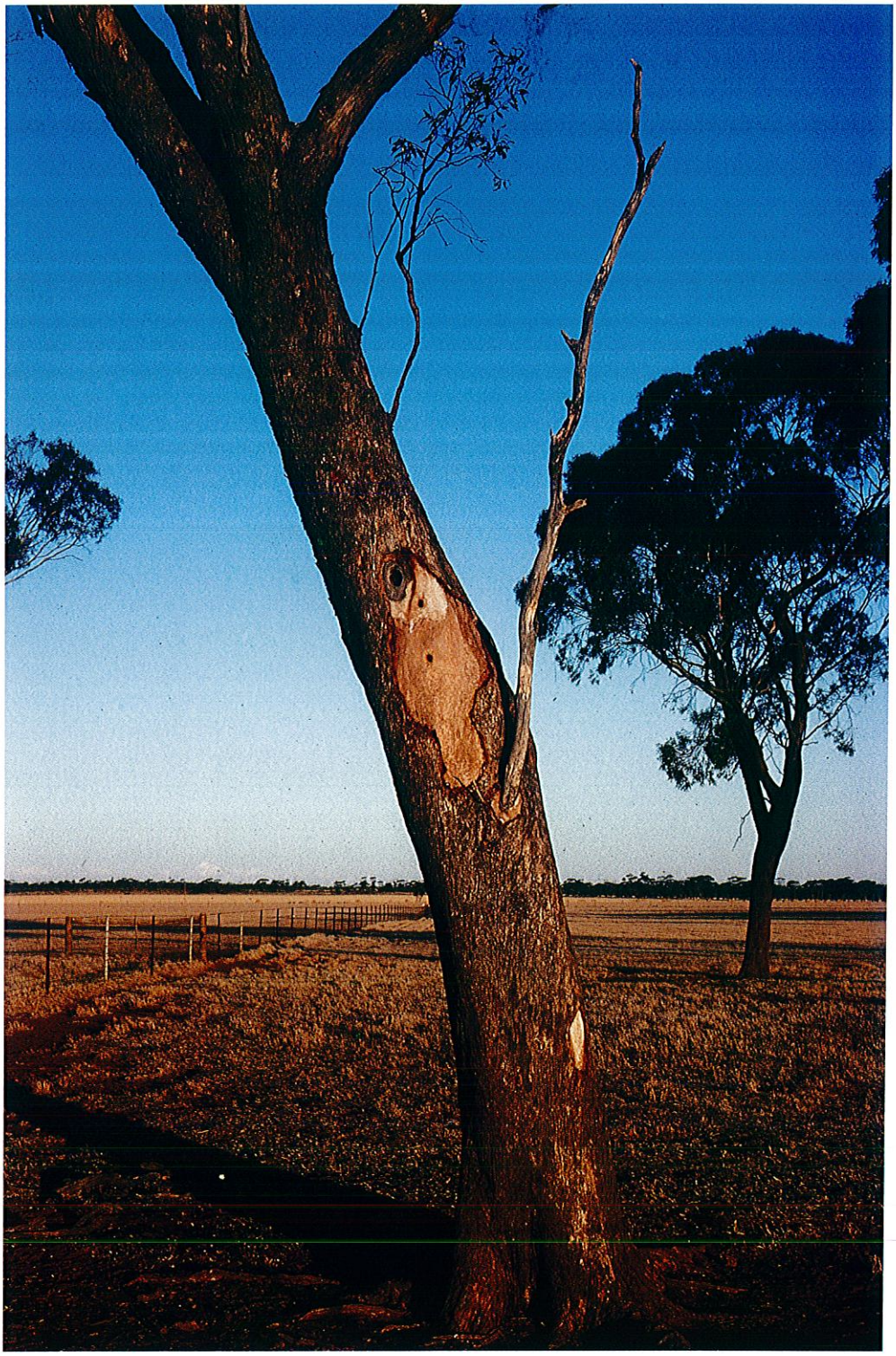


Top: *Older residents often have a fund of knowledge about their district. Here, Gil Gardener locates a boodie warren that was active when he was a boy.* (Penny Hussey)

Above: *Tasmanian blue gums have been planted here to lower the water table and so control waterlogging and incipent salinity and provide a pole crop.* (Penny Hussey)

Left: *Sheep have removed what they can of this warted cypress-pine, creating a definite browse line. Moorine Rock.* (Penny Hussey)

Next page: *Galahs have stripped the bark from around this nesting hole in a red morrel. Two years after this photograph was taken, they completely ringbarked the tree, which then died. Waddi Forest.* (Penny Hussey)



tree cover is evident all over Australia and is called rural tree decline or sometimes rural dieback.

While this is a concern, the loss of the shrub and ground layer which usually occurs before the trees die, often goes unnoticed.

Stressed trees show loss of vigour and dying back of branches, and this may lead to tree death. There are numerous factors which contribute to tree stress, and usually a site will have several of them operating at once.

Stress factors which are associated with rural tree and shrub decline:

- increased physical exposure caused by isolation
- changes in soil structure
- changes in hydrology
- salinity
- nutrient imbalance
- air pollution
- old age
- climatic extremes
    - drought
    - flood
    - frost
- fire
- mistletoe
- fungal attack
    - canker fungi
    - root-rot fungi (dieback fungi)
- severe insect attack
- other faunal damage
- herbicides
- competition with introduced plants (see chapter 6).

Each of these factors is discussed below, with some suggestions for alleviating the effects wherever possible.

Increased Physical Exposure Caused by Isolation

Many rural trees were left isolated, either as individual trees or as small stands, when agricultural clearing took place.

After clearing, strong winds have direct access to the tree and can cause considerable damage, as the root extent and branch diameter developed to support the crown while the tree was buffered from the winds' worst effects by the presence of surrounding vegetation.

Not only does wind cause physical damage; hot dry winds cause an increase in transpiration, especially during summer. This leads to water stress, and in some cases (tuarts, for example) leaf scorch can occur, followed by leaf fall. Wandoos, in common with some other eucalypts, respond to extreme water stress by having whole branches die back and sometimes drop off.

The problems of increased water loss are compounded by the increased sunlight received by isolated trees. Without mutual shading, the direct heat of the sun causes more water stress, and the tree increases its transpiration rate in order to cool the overheated leaves.

Suggested mitigating action: plant a buffer between the remnant and the direction of the prevailing winds.

Soil Deposition in Remnant Vegetation

Windstorms deposit debris - soil, weed seeds, straw, manure - in remnants. This will cause severe degradation; for example it:

- covers the original soil profile with its micro-organisms, seed store, orchid tubers, etc., preventing their growth and destroying the natural cycling of soil nutrients
- buries rootstocks

- is often water repellent, causing greater run-off and less infiltration
- limits oxygen penetration to roots adapted to grow close to the surface
- contains seeds of many plants which in the remnant become weeds, for example wild oats, turnip, capeweed
- often contains a high concentration of phosphate from chemical fertilisers. Many native plants - especially in the banksia family - are killed by a high level of phosphate. Increasing phosphate levels also encourage weeds
- often creates ideal habitat for the establishment of feral animals such as rabbits and foxes.

The result is severe degradation of the remnant community, starting with loss of the ground and small shrub layers and ending with death of the trees and a remnant dominated by exotic weeds.

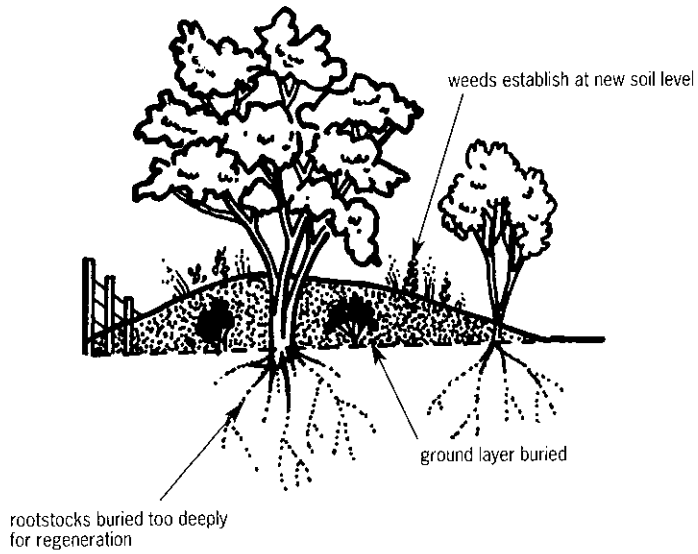
Suggested mitigating action: plant a buffer between the remnant and the prevailing winds.

Changes in Soil Structure

A lack of leaf litter leads to a decrease in soil fauna and organic matter build-up within the soil, resulting in loss of soil structure. This is compounded by compaction through stock trampling which reduces water and air infiltration into the soil system. This all creates a less favourable environment for the growth of plant roots and increased flooding and erosion downstream.

Suggested mitigating action: exclude stock from the bush remnant.

Figure 5.5 Effects of wind-blown debris deposition in remnant vegetation



Changes in Hydrology

Alterations in the water table caused by clearing can eventually lead to the death of remnant trees. Sometimes this can happen quite rapidly. For example, on the property of Peter Hilder at North Dinninup, it took ten years from the time of clearing for trees left along the streams to begin to show signs of stress from waterlogging. Artificial changes in drainage patterns can also affect remnants. Remedy this by:

- redesigning drainage systems to minimise effects on remnants
- when designing water management plans for the property, avoid draining surplus or saline water into remnant vegetation as it will inevitably cause degradation.
- in wetlands, water levels should be managed to retain as near the original conditions as possible.

Loss of heritage value

A section of Goldfields Road in Trayning Shire has been declared a Flora Road to protect its floral and historical heritage value. The road reserve is mostly 40 m wide, with only five m disturbed by a track, one of the historical routes to the Goldfields. The undisturbed section carries a very rich community of typical heathland plants - except where a fold in the ground concentrates paddock run-off. Here the native shrub community is replaced by a cover that is 90 per cent paddock weeds. Although changes in hydrology might be implicated, the most likely cause is nutrient enrichment.

It would now be very difficult, if not impossible, to return this area to its original state.

Suggested mitigating action: revegetation and farming practices designed to control groundwater.

Salinity

The rise of saline groundwater has undoubtedly contributed to rural tree decline in many areas. A classic example is provided at Lake Toolibin, where a co-ordinated replanting programme is attempting to control salinity and increased waterlogging, and so reverse the vegetation decline.[18]

Suggested mitigating action: various measures designed to control salinity.

Nutrient Imbalance

The use of fertilisers such as superphosphate to grow introduced crop and pasture species in Australia has altered the original soil nutrient balance. This may affect the growth of remnant vegetation by eliminating some species and favouring others, thus altering the species composition of the remnant. This can be seen very clearly where run-off from paddocks crosses roadsides which still have good native vegetation.

Suggested mitigating action: minimise nutrient addition to remnant vegetation by:

- excluding stock
- spreading superphosphate when the wind is blowing away from the remnant or not applying it for the first run past the remnant. As discussed above, this is most important where the remnant contains plants from the banksia family, for example: banksias, hakeas, grevilleas, dryandras, stirlingias or smokebush
- avoid channelling nutrient-rich water through the remnant
- if the remnant is on a slope with paddock

above it, grade a bank on the contour above the remnant to catch and hold nutrient-rich water (and weed seed). Advantage could be taken of this to plant one or two lines of plants to utilise the extra nutrients and water.

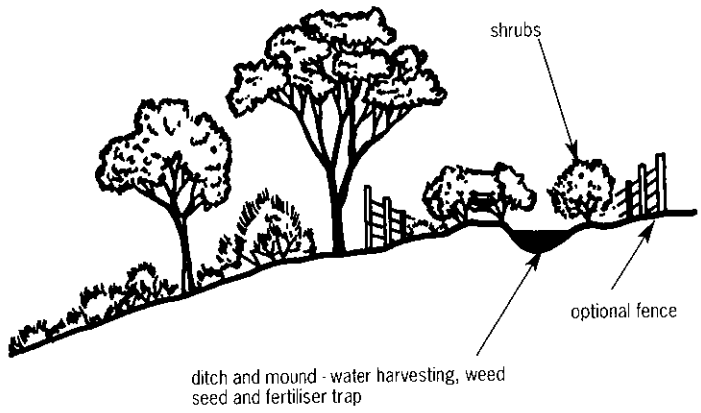
This is especially important if the remnant contains a freshwater wetland, as increased nutrients, especially phosphorus, lead to eutrophication. This condition occurs when a massive growth of blue-green bacteria, supported by high levels of nitrogen and phosphorus, release toxic waste products into the water. As things begin to die, a massive growth of decomposers uses up all the oxygen, accelerating the dying process. Once this condition occurs, it is extremely expensive to try and correct it, as the millions spent annually on the Peel-Harvey Inlet clearly demonstrates. Running water through a filter of actively-growing plants removes many of the nutrients and, if forage plants are used, it would benefit both the wetland and farm production.

Air Pollution

In more densely populated countries of the industrialised world, air pollution is a major contributor to tree decline. Acid rain from coal-fired power stations and industrial complexes is destroying coniferous forests and wetlands in much of northern Europe and North America, while photochemical smog, mainly caused by car exhausts, is a killer in the mountains of California. Other industrial emissions can also be damaging to plants, as visitors to Queenstown in Tasmania will be well aware.

WA's small population has saved the State from the worst impacts of industrial air pollution. Perth is one of the very few modern cities where blue skies in summer

Figure 5.6 Minimising nutrient and weed seed input into remnant vegetation



are not commonly obscured by haze. However, we do have excellent conditions for the development of photochemical smog and it is becoming more evident over Perth. With regard to industrial emissions, problems exist in the Goldfields, where Kalgoorlie may soon be able to claim that it is the world's highest emitter of sulphur dioxide,[19] and around Kwinana and Muja. These are not considered to have the magnitude of overseas effects, although it would be short-sighted to just ignore them.

Suggested mitigating action: there is not much an individual land manager can do about this problem.

Old Age

There is currently little evidence of the normal life span of WA trees, except for wattles, which are known to be relatively short-lived. In many agricultural areas, the trees were already mature when they were isolated within paddocks so a natural decline, due to old age, may be involved in some cases.

Suggested mitigating actions: ensure that regeneration is occurring, so that young plants can eventually replace the old.

Climatic Extremes

Unusual extremes of climate will cause plant stress, for example the dramatic crown death of wandoo in the Great Southern following two days of record heat in February 1991, or the decline shown by marri in some frost pockets on the eastern edge of the jarrah forest following a record 13 days of frost in the winter of 1990. Most of these plants seemed to have recovered during the following winter.[20]

Drought

Long dry periods are a feature of the WA climate. Most plants have strategies to survive but extremes cause plant deaths, with consequent repercussions on the whole ecosystem.

Drought stress also causes plants to respond more slowly to fungal invasion, and may predispose them to insect attack. In North America, for example, it has been shown that stressed white oaks release chemicals that attract adult jewel beetles, which then lay eggs on the trees. Their larvae are borers, tunnelling through the wood.[21] This effect may well occur in WA, although it has not been investigated here.

Drought has most effect on shallow soils. It is common for the plants around granite rocks to start to die first in the shallowest soils closest to the rocks. Seedlings re-invade during the following wet seasons. Thus there is a natural change in the composition of the vegetation community.

In general, stress caused by drought is probably an important factor which sorts out plants in a community. After a disturbance such as a fire, there is often a very dense regeneration of seedlings. Competition between them over the following years sees only the strongest survive.

The effect of competition can often be seen very clearly in planted tree belts. As they grow larger and require more resources, they interact and in times of stress, deaths occur.

Within agricultural regions, it is possible that the effects of drought on remnant vegetation may be exacerbated. Changes in vegetation cover have meant in many areas a change in soil water regimes. Microclimatic effects due to increased exposure, together with increased soil temperatures caused by a lack of protective leaf litter, lead to increases in water use. In addition, increase in soil nutrients leads to a greater quantity of leaf growth than would have originally occurred at that site. When drought does

occur, this extra leaf area could be a handicap to survival.

Flood

In addition to simply uprooting plants which happen to be in their way, floods can cause waterlogging in low-lying areas and this can cause severe decline in remnant vegetation. Even short duration floods in summer can be damaging as the high soil temperatures contribute to the problem.

The wheatbelt tends to have very low topographic relief, with shallow broad drainage lines designed to carry lower volumes of run-off than is now the case after clearing. The result is that flooding and waterlogging have increased because the natural drainage cannot get the water away fast enough.

Waterlogging and decline of jarrah

In jarrah, DEC's Elaine Davison has shown that lack of soil oxygen caused by waterlogging leads to tyloses, outgrowths which block the xylem vessels and so restrict water movement through the plant. The longer the period of waterlogging, the more vessels are blocked. They remain blocked even after normal soil conditions are restored, and so the tree is permanently handicapped.

In addition, waterlogged roots which are respiring anaerobically produce ethanol which attracts the spores of *Phytophthora*, the jarrah dieback fungus.

Sites which become waterlogged are poor locations for maximum growth of jarrah.

On the coastal plain, many remnants are flooded during winter but dry out in summer. Altered water regimes through drainage or rising watertables change the duration of flooding. This affects the survival of the remnant.

Normally soil has air in pockets between the soil particles and this air is important for oxygen uptake (breathing) by roots and soil creatures. However, in waterlogged soil, the only oxygen available is that dissolved in the soil water. The activities of soil micro-organisms soon use this up, and the soil water becomes anaerobic (no oxygen available). At temperatures of +20° C this can happen within one day. Plant roots then switch to anaerobic respiration (produce energy without oxygen), but this is less efficient and toxic products build up in the cells.[22]

Frost

In inland areas of WA, frosts are common, and the plants are adapted to survive them. However, isolation of vegetation and thinning of the canopy may increase the severity of the frost's effects, especially on understorey.

Long periods of frost and frosts where they do not normally occur can lead to plant stress. A severe frost in October in the early 1980s severely damaged some stands of box poison *(Gastrolobium parviflorum)*, in both Boyagin and Tutanning Nature Reserves. The lengthy run of cold nights in the winter of 1990 caused decline in several plant species, including marri along the Brookton Highway and sheoak north of Yanchep. In addition, the severity of fungal cankers on branches appears to be greater following frost.[23]

Suggested mitigating action: plants survive the stress of climatic extremes better if they are healthy, therefore any measure which increases the health of the vegetation will help.

Fire

Fire may cause severe plant stress and death. It also stimulates regeneration. It is so important in the management of WA ecosystems that it is considered in detail in chapter 9.

Mistletoe

There are several species of mistletoe in WA. They chiefly parasitise eucalypts, sheoaks and wattles, though other plants such as hakeas can also be affected. They draw water and nutrients from a branch and a severe infestation can debilitate, or even kill, a tree.

Mistletoes are spread by birds such as honeyeaters and mistletoe birds, which eat the fruits and excrete the seeds onto branches. Because of lack of other habitat in agricultural areas, the birds may be restricted to a small group of trees, such as along a road verge, and thus the mistletoe infestations may become locally denser than before clearing.

Possums are thought to eat mistletoe plants and so act as a controlling influence. Their decline in agricultural areas could be another reason why mistletoes are apparently increasing. In addition, mistletoes are sensitive to fire and usually killed during wildfires, which now seldom occur in isolated remnants.[24]

Suggested mitigating action: the only practical method of mistletoe control is pruning infected branches. Chemical control by trunk injection has been tried but is risky on native plants as it can also damage the host. In addition, many of the herbicides trialled have since been banned, as they have been linked to health problems.[25]

Fungal Attack

Many fungi interact with plants. This can be beneficial, as with the fungi which live in mycorrhizal association with plant roots. Other fungi are particularly damaging to native vegetation.

The honey fungus (*Armillaria luteobubalina*) is a native to WA. It is having a severe effect on coastal vegetation, killing everything from wattles to tuart (*Eucalyptus gomphocephala*), in some cases causing such devastation that the sandhills start eroding.[26] In the jarrah forest its effect is patchy, but it increases in severity in the wandoo belt. It kills not only jarrah but marri and many understorey species as well, while wandoo is particularly susceptible.[27] Little is known of its biology, and there is no cure. Other fungi contribute to vegetation decline and the two most important, canker and root-rot, will be discussed in detail later. In general, fungi have most effect on an already weakened or stressed plant, while healthy plants are better able to withstand fungal attack.

Suggested mitigating action: any management which minimises plant stress will enable them to more easily combat fungal attack.

Canker Fungi

In the bark of most living trees are numerous small fungal infections. They kill twigs in the lower crown and cause lesions - called cankers - in the bark of the main stem and roots. The fungi are common and widespread and enter the plant usually through a wound, perhaps made by wind or insect damage.

There are two main types of canker fungi, annual and perennial. Annual cankers are relatively easily healed, but in perennial ones the, cambium and adjacent wood are all killed. The dead bark sloughs off and the wood is left as an exposed scar. In stressed trees, the dead area of bark and wood may girdle the trunk and branches, and lead to death of the parts above the infection.[28] In addition, the dry, loose bark burns well, and provides an excellent site for increased fire

damage to occur.

Unless the tree is severely stressed, especially by drought, it can fight fungal attack by walling off the infection site and producing compounds that are toxic to the fungi, in a process which is similar to the immune system fighting disease in humans. However, this process uses up a lot of energy, and plants under stress may not have the starch reserves available to do this. Thus, like humans with malnutrition, what would be a relatively minor infection in a healthy tree spreads relentlessly once the host's defences are down.

Visible sign of the fight against injury in eucalypts is the exudation of kino, or gum, from damaged bark areas. The kino contains polyphenols which are effective in inhibiting both fungal and microbial growth. Healthy trees are able to rapidly regenerate both cambium and bark.

Recently canker fungi have been noted in epidemic proportions attacking banksia heaths. They spread and grow well in very hot, wet summers, infecting stems near their tips and moving downwards to possibly kill the plant.[29]

Suggested mitigating action: wherever possible, minimise factors which cause stress, and so permit the plant to effectively combat the infection.

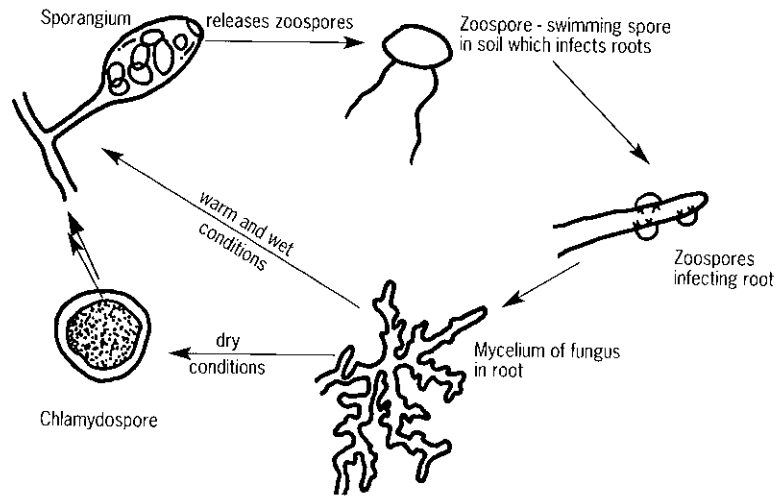
Canker fungi can be spread during harvesting of flowers and seeds, so care should be taken during commercial operations.

Root-rot Fungi (dieback fungi)

Many parasitic fungi attack plant roots (including the native honey fungus), causing damage and possibly death to the plant.

Root-rot fungi of the genus *Phytophthora*

Figure 5.7 Life cycle of Phytophthora cinnamoni in Western Australia



death of plants in bushland [30]

Damage caused by *Phytophthora* cannot be recognised by looking for visible signs of the fungi itself. Instead, infections are diagnosed by looking at the symptoms shown by affected vegetation.

A combination of four factors should be noted: -

1. The species affected. *Phytophthora* kills some plants but not others. Suspect the fungus if the following are dead or dying: banksia family, heath family, pea family, hibbertia family, grasstree or zamia. Plants which will not be affected include reeds and rushes, kangaroo paws and marri.

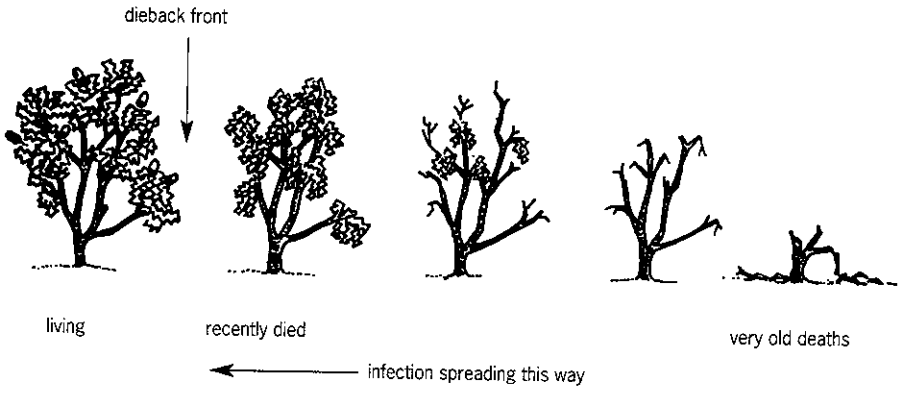
2. The pattern of distribution of the affected plants. *Phytophthora* is spread by water, by movement of infected soil or directly from one host plant root to another. Thus infected sites will show a pattern of disease spread outwards from an initial area of infection. The region where plants are currently dying is called the "dieback front".

3. The drainage, soils and topography. The growth of *Phytophthora* is favoured by wet ground, so plants growing along drainage lines or in flooded areas are the most susceptible. Nevertheless, it can and does exist on well-drained areas such as white sand, as long as suitable host species are present.

4. The presence of a vector which may have introduced the disease. The commonest vector which introduces *Phytophthora* into an area is the movement of vehicles, on roads, tracks or off-road. Also important are the movement of stock and flowing water.

If all four factors indicate an infection at a site, then *Phytophthora* is likely to be present.

Figure 5.8 Pattern of deaths due to infection



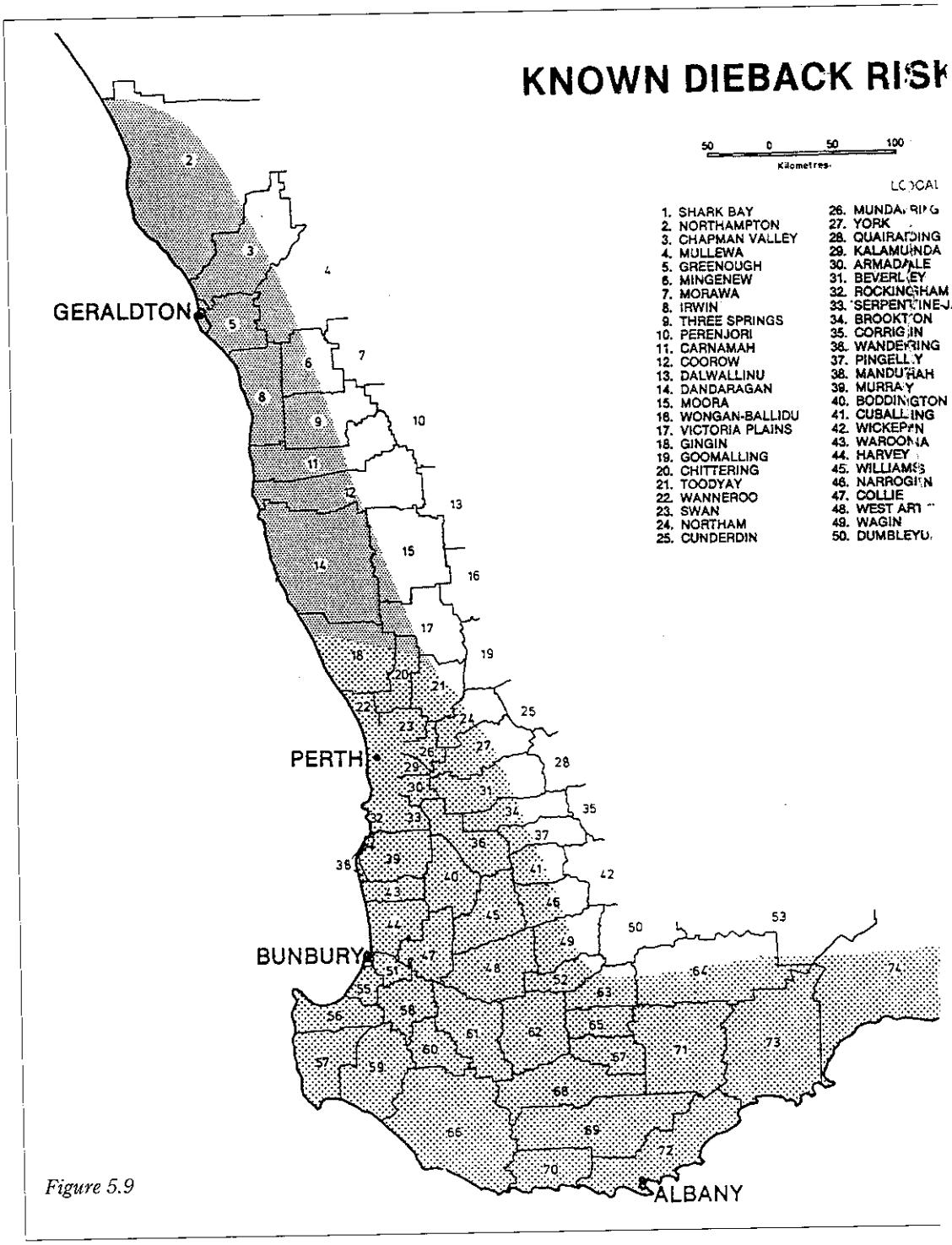
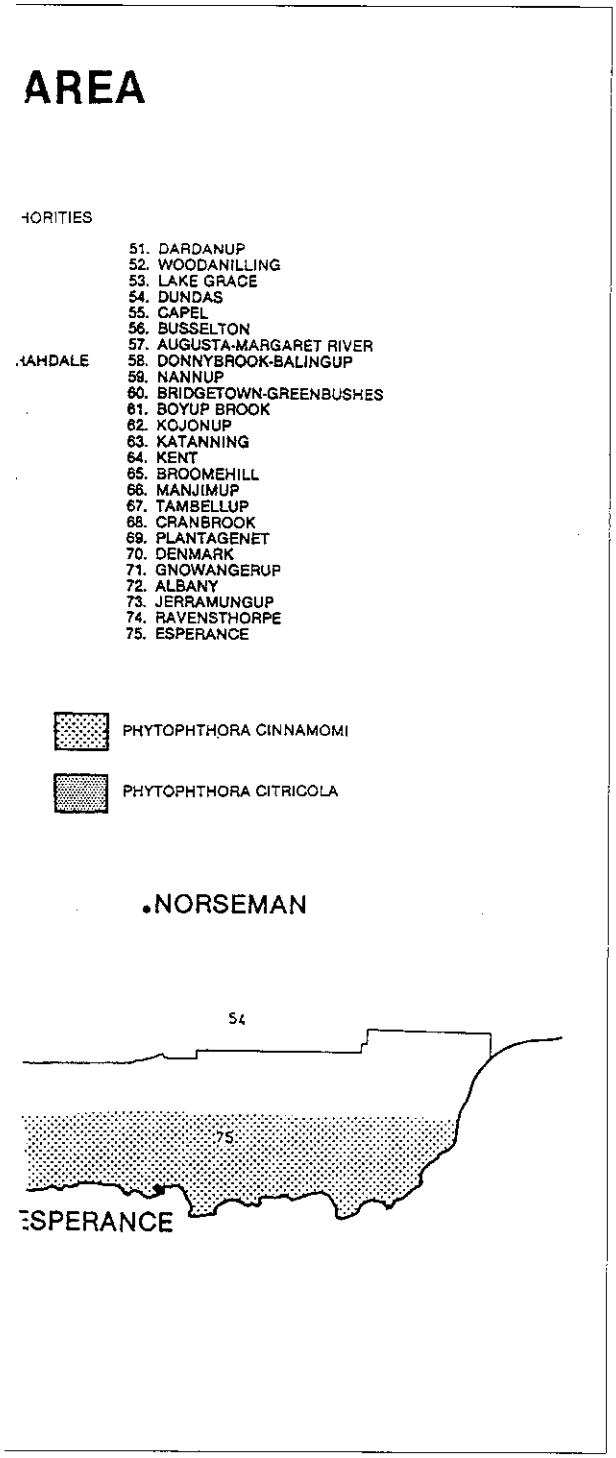

KNOWN DIEBACK RISK
50 0 50 100
Kilometres
LOCAL
1. SHARK BAY
2. NORTHAMPTON
3. CHAPMAN VALLEY
4. MULLEWA
5. GREENOUGH
6. MINGENEW
7. MORAWA
8. IRWIN
9. THREE SPRINGS
10. PERENJORI
11. CARNAMAH
12. COOROW
13. DALWALLINU
14. DANDARAGAN
15. MOORA
16. WONGAN-BALLIDU
17. VICTORIA PLAINS
18. GINGIN
19. GOOMALLING
20. CHITTERING
21. TOODYAY
22. WANNEROO
23. SWAN
24. NORTHAM
25. CUNDERDIN
26. MUNDARING
27. YORK
28. QUAIRADING
29. KALAMUNDA
30. ARMADALE
31. BEVERLEY
32. ROCKINGHAM
33. SERPENTINE-JAR
34. BROOKTON
35. CORRIGIN
36. WANDERING
37. PINGELLY
38. MANDURAH
39. MURRAY
40. BODDINGTON
41. CUBALLING
42. WICKEPIN
43. WAROONA
44. HARVEY
45. WILLIAMS
46. NARROGIN
47. COLLIE
48. WEST ARTHUR
49. WAGIN
50. DUMBLEYUNG
GERALDTON
PERTH
BUNBURY
ALBANY

Figure 5.9



are the most devastating, especially the introduced *Phytophthora cinnamomi*, whose symptoms are notorious as "jarrah dieback". These fungi kill a wide range of species and cause severe damage to some vegetation types, affecting the timber, water catchment, recreational and aesthetic values of the bushland. Loss of vegetation also has a severe effect on native fauna.

Root-rot fungi live in the soil and plant roots and are spread by water or the movement of infected soil and roots. Moist, warm soil conditions are most conducive to its spread. Some plants are not affected by the fungus, some receive a slight set-back, and others are swiftly killed. The worst affected native plant families are banksia family, heath family, hibbertia family and pea family. In addition, some orchard crops such as avocados, horticultural crops such as proteas and even agricultural crops such as lupins, are at risk.

Elimination of the disease from a site is difficult and expensive. Treatment of individual plants and small areas of infection is possible using phosphorus acid applied as trunk injections and/or a foliar spray. These techniques, along with the application of fungicides as a soil drench, have been used successfully in horticultural situations; however, broadscale management concentrates on limiting disease spread. Contact DEC for up-to-date advice.

Most new infections are caused by human activities which carry infected soil from place to place. By controlling those practices known to spread the disease, its spread can be slowed down. The area of the state where *Phytophthora* is likely to occur is shown in figure 5.9.

The result of this devastating disease is to permanently degrade plant communities. This will mean:

- part of our heritage will be lost forever
- since the major honey-producing plant families are among those that are

destroyed, there will be a lot less food for nectar-eaters such as honey possums, birds or insects such as bees

- there will be fewer attractive wildflowers for commercial harvest or tourism
- there will be a loss of utilisable timber and lack of regeneration in affected areas
- the quality of the water and stability of the soil may be affected by vegetation loss
- the range of plant species, native and introduced, that can be grown on the land will be reduced forever.

If tree decline is occurring within the known range of *Phytophthora*, then infection with root-rot fungi is a possible cause. Field inspection can confirm this.

If *Phytophthora* is suspected at a site then every effort should be made to keep it from spreading. Equally, if susceptible vegetation within the range of *Phytophthora* appears to be free of the disease, it would be sensible to take precautions to prevent it entering.

Suggested mitigating action: the current control methods are hygiene measures which aim to prevent the movement of infected soil and water to uninfected sites. These include:

- ensure that all machinery entering your property is free of soil and mud
- minimise the movement of vehicles or stock across the boundary between infected and uninfected areas
- ensure any machinery entering a remnant is not carrying soil from infected areas. (This is an important consideration if a contractor is to be employed.) If in doubt, use wash-down or compressed air blow-down techniques to ensure machines are clean
- take care not to use road-making material (i.e. gravel) from infected sites. (Before it was understood what was causing jarrah dieback, gravel was often taken from graveyard sites where all the trees were dead, in fact from the disease. This, and movement along streams and in mud on vehicles, are the most important ways the disease was spread through the jarrah forest.)
- wherever possible, activities in which soil may be spread by heavy machinery and vehicles (this is especially important for activities such as fence construction or firebreak maintenance, both of which have a very high probability of moving infected soil)
- work in mini-catchments. Avoid moving material from one catchment to another, i.e. do not work uphill or across catchment boundaries.

For further information and advice about the presence of *Phytophthora* dieback and suitable hygiene measures, consult DEC.

These basic farm hygiene techniques are important controls against the spread of weeds, rye-grass toxicity and animal diseases.

Severe Insect Attack

Some herbivorous insects occur in such numbers that they contribute to vegetation decline. Under natural conditions many outbreaks were probably controlled by predators such as birds (see chapter 2) but once the balance is upset this is not as effective. In remnant vegetation, probably the most important insects are the defoliators and the borers.

Locust plagues provide an extreme example of the damage that can be done by large numbers of leaf-eating insects (defoliators). In the summer of 1990-91 they caused devastation over wide areas, but only to the plants which they preferred. Even where numbers of insects were immense, mature trees of York gum and jam were ignored, while sheoaks, saltbush and

samphire were stripped of all green material.

Wingless grasshoppers are severe defoliators of marri in some areas of the coastal plain. They climb the tree to eat the leaves and after three to four years of consecutive attacks, a mature tree will be killed. The insects drop off and lay their eggs under the crowns of the trees.

One of the factors influencing insect feeding is the nutritional quality of foliage. For any one particular species of tree, those growing in more fertile ground produce more nutritious foliage, which increases insect growth rate and maturation speed and so increases the severity of the attack.

Borer is a general term given to insect larvae which tunnel through stems and roots, feeding as they go. The insects may become quite large - as big as a finger - and live for several years inside a host plant. Their activities cause a lot of damage, weakening the plant - and lowering its timber value. They may also provide sites for fungal infection; indeed, they may need to have fungi present to soften the wood before they can digest it.

Sometimes a borer gallery may circle a branch, ringbarking and killing it. The gallery can occasionally be seen as a raised line running around the branches, especially in wandoos. At Narrogin, borers are causing the widespread death of marris, often the only tree left in many paddocks, which has implications for future water balance and stock shelter.[32]

Some animals do attack the borers, even protected as they are within the plant tissues. Athol Douglas, formerly of the WA Museum, reported that bilbies, which were once abundant in the wheatbelt, commonly dug down to plant roots and extracted the borers from them.[33] Several birds, notably parrots and cockatoos, remove borers from the aerial parts of plants. Flocks of white-tailed black cockatoos congregate on suitable trees, such as acorn banksia (*Banksia prionotes*), ripping off the flowers to get at the grubs living in the central axis. On marri trees, the cockies leave what looks like a vertical chain saw cut as they tear off the bark to expose the borer tunnel beneath. These wounds become a prime site for infection by fungi, especially those that cause cankers.

Foliage: nutritional quality and insect attack[31]

Rural tree decline in NSW has been investigated by many people. Jill Landsberg looked at the relationship between the nutritional quality of foliage and the extent of insect defoliation. Her work supports a sequence of events which goes rather like this:

- sheep camp under trees and their droppings raise the soil nutrient level
- trees at these sites have more nutritious foliage than usual
- defoliating insect larvae grow larger and mature more quickly on more nutritious leaves; therefore more generations of insects are born during the season
- females of these insects will produce more eggs if they are larger and have high nitrogen in their diet; therefore more insects will be born.

Increased nutrients lead to an increasing level of insect attack on trees in pasture situations. To minimise this effect, nutrient levels under trees must be reduced.

Suggested mitigating actions:

- minimise extra nutrients around remnant vegetation by excluding stock and limiting nutrient input from paddocks
- regenerate the understorey to encourage a diverse community which would include the predators of the problem insects - birds and parasitic insects

- for wingless grasshoppers, egg beds under trees can be sprayed with insecticide at hatching time, or a "hopper stopper" collar can be attached to the tree's trunk.

Other Damage by Fauna

As indicated above, parrots and cockatoos can do extensive damage to plants while they are searching for food. The damage done to grass tree (*Xanthorrhoea* spp.) is of particular concern. The birds pull out the youngest leaves and damage the growing tip; grass trees may not recover from this. It seems that the birds actually learn this behaviour, and the knowledge is soon passed through the flock.

Other hole-nesting birds may damage a tree during the breeding season. Galahs are notorious for this, as they actively chew off the bark around their nesting hollows. Where large flocks are breeding in an isolated stand of trees, this behaviour can contribute to the stand decline.

Suggested mitigating action: if there is a clear case of damage, bird numbers could be controlled (see chapter 8).

Herbicides

The use of herbicides in normal farm operations can damage adjacent remnant vegetation if care is not taken. The most usual way in which this occurs is by spray drifting from the paddock onto desirable plants. Unfortunately, some native plants, such as orchids and everlastings, are not only very susceptible to herbicides but may be growing vigorously at exactly the same time as paddock weed control occurs. They can easily be eliminated from small remnants unless careful and appropriate application methods are used.

Suggested mitigating actions:

- eliminate the possibility of drift into the remnant by working only on still days
- consider turning off the spray, or at least the outer nozzles, when making the first run past a remnant
- buffer strips planted to mitigate wind effects are also effective in minimising spray drift into the remnant
- wherever possible spray in cool, moist conditions in the morning or early evening
- avoid spraying in hot, dry or windy conditions
- if the remnant vegetation is on one side of a paddock only, spray when there is a slight breeze blowing away from that area
- avoid using misters
- reduce boom speed and height
- reduce system pressure and use large nozzle sizes
- use appropriate equipment and keep it well serviced.

Competition with Introduced Plants

Weeds are generally aggressive colonisers. They compete with established native plants and severely limit seedling regeneration.

For a discussion of the effects of weeds on remnant vegetation, and methods of weed control, see chapter 6.

6 Problem Plants

- **Exotic plants**
- Effect of weeds on bush
- Legal aspects
- Methods of control
- Planning a weed control campaign
- Management strategies for specific types of weeds
- **Native plants**
- Poison plants
- Tree competition with crops

Watsonia

Exotic Plants

Western Australia has about 8 000 scientifically described and named plants, with approximately 2 000 more waiting to be named. Of these, about ten per cent have been introduced from outside the State; that is, they are exotic plants.[1] Most of the introductions came with European settlers, who not only brought in crops and ornamental plants but also, often unwittingly, numerous other species. Many of these plants could not survive without human care and cultivation but others have found the conditions very much to their liking and have become naturalised. When these cause problems they are called weeds.

A weed is a plant growing where it is not wanted. In remnant bush, where the aim is to retain a healthy native vegetation community, introduced plants which replace the original native vegetation are environmental weeds. Environmental weeds are defined as those species that invade native communities or ecosystems and are undesirable from an ecological perspective but not necessarily from an economic one.

Long-settled areas and sites close to settlement usually show the greatest number of exotic plants, especially if the site has been disturbed. Grazing, logging, rubbish dumping, stock and vehicle movements may all create ideal sites for weed invasion and several studies have shown that in the absence of disturbance, weeds find it hard to establish.[2]

Exotic Plant Introduction

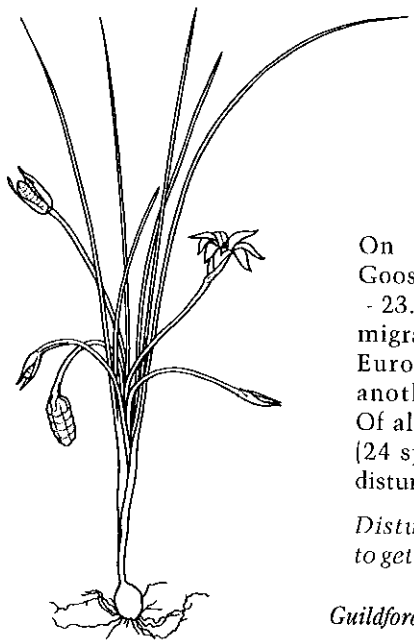
All over the world, wherever people have settled, their farm and garden weeds have travelled with them: in animal foodstuffs, on goods or vehicles, even in the soil around potted plants.

It seems likely that European settlers brought in most of the 1 000 or so recent plant invaders to Australia. Some were imported deliberately as crop, pasture or garden plants. Many of these came from South Africa. Cape Town was the last port of call for most ships travelling to Western Australia, and has a similar climate, so settlers would have picked up stock and hay for feed together with pot plants, bulbs and seeds for the garden. Plants such as arum lily (*Zantedeschia aethiopica*) and cape tulip (*Homeria* spp.) arrived in this way. African lovegrass (*Eragrostis curvula*) was brought deliberately into WA in 1960 and trialled as a possible pasture species.[3] Perennial veldt grass (*Ehrharta calycina*) was probably a component of hay used for ship-board feed. Doublegee was originally imported for use as a salad vegetable! Current quarantine laws seek to prevent the introduction of plants that could become weeds.

Once they enter Australia, the movement of stock and vehicles assists the spread of plants. Skeleton weed (*Chondrilla juncea*) is well known for its ability to hitch-hike on trains from the eastern states. The taxpayer, and grain growers, via a levy, foot an annual bill to ensure that this troublesome weed does not get established here.

Conditions for Establishment

In many cases, the most important factor which enables introduced plants to get a hold is disturbance of the soil and original plant community - the edges of roads and tracks show this most clearly. Plants which respond to open conditions by rapid germination and growth are called disturbance opportunists, and there are many native plants - for example spear grasses, flannel flowers and everlastings - which respond in this way.



Gooseberry Hill, plant migrant hostel[4]

On the north-facing bushland slope of Gooseberry Hill, Kalamunda, 128 plant species - 23.5 per cent of all species recorded there - are migrants. Sixty-three per cent of them are from Europe, mostly the Mediterranean, while another 21 per cent come from South Africa. Of all these exotics, however, only 19 per cent (24 species) are found in the bush, away from disturbed areas such as roads and tracks.

Disturbance is a vital factor in allowing weeds to get established.

Guildford grass

Another factor which helps exotic plants get established is an increase in soil nutrient levels. Many Australian soils are naturally rather infertile and inhibit the growth of plants that are adapted to more fertile soils, but once nutrients are added they can get going. In many bush remnants this is clearly demonstrated by the growth of capeweed (*Arctotheca calendula*) and wild oats around rabbit dung piles. Rabbits disturb the ground and raise nutrient levels. This effect can also be seen around the edges of ant mounds, such as those created by meat ants.

Effect of Weeds on Bush

Introduced plants have a major effect on natural vegetation communities. They:

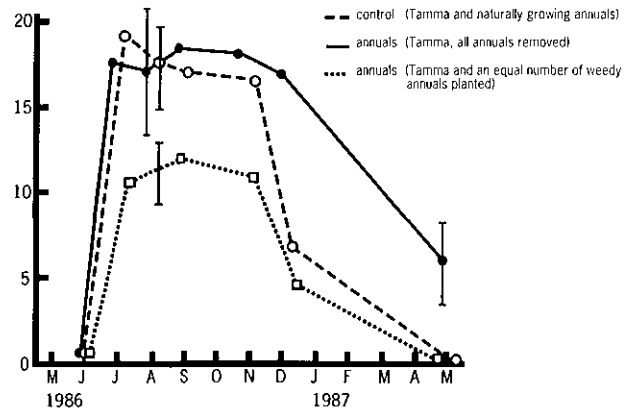
- compete directly with established native vegetation, inhibiting growth and displacing species
- replace diverse native plant communities with more uniform weed communities, i.e. they change the species composition of an area
- inhibit native plant regeneration through competition
- alter the nutrient cycling of natural communities
- may change the soil acidity
- may increase the fire hazard
- alter the resources available for fauna by
  - changing the habitat, for example from shrubs to grass
  - changing the food availability, for example by losing nectar-producing native shrubs and ground layer plants.

Effect of competition on regeneration of native species[5]

To test whether competition really does limit native seedling establishment, CSIRO's Richard Hobbs and Lyn Atkins established some trial plots in an area of bushland north of Kellerberrin. They planted tamma (*Allocasuarina campestris*) seedlings and noted their survival rate under three conditions (see graph).

It can be seen that the only plots where seedlings survived the summer was where there was no competition from annuals.

This emphasises how important weed control is when establishing revegetation by direct seeding.



Legal Aspects

Declared Plants

Plants, both native and introduced, that are or may become a problem to agriculture, can be declared under the Agriculture and Related Resources Protection Act, administered by the Agriculture Protection Board (APB). When it is declared, a plant is placed in one or more categories according to the control strategies considered appropriate.

The factors considered when categorising plants are:

- the impact of the plant on agricultural production and the community in general
- whether the plant is already established in an area
- whether control is economically feasible.

The declaration could be for the whole State or for smaller areas, even for an individual property.

Landowners with Declared Plants on their property are obliged to control them at their own expense. Landholders may effect the control themselves, or employ a contractor to do it. Contact the APB for advice.

Pest Plants

A Local Government Authority can prescribe a plant a "pest plant" and can then make a by-law for its control in accordance with the Agriculture and Related Resources Protection Act. A pest plant could be any plant (other than a declared plant) that may adversely affect the value of property or the health, comfort and convenience of the inhabitants of the district.

None of these categories refers specifically to environmental weeds although Declared Plants and Pest Plant legislation are often used for this purpose.

Use of Chemicals

There are also a number of regulations which apply to the safe handling and use of agricultural chemicals such as herbicides used for weed control. Most of these come under the Health Act and it is the responsibility of all operators to follow them.

Basically:

- read the label and prepare and use a herbicide only as directed on the label
- wear recommended protective clothing
- spray only in suitable conditions
- store and dispose of containers safely.

Restrictions on Spraying

Some hormone-like herbicides (for example Dicamba, 2,4-D or picloram) can also affect crops such as grapes and tomatoes, so the use of these are specifically regulated under the Agriculture and Related Resources Protection (Spraying Restrictions) Regulations and the Aerial Spraying Control Act.

Persons who wish to use these types of herbicides within 50 km of the Geraldton Post Office or within the Swan Valley or within 10 km of a commercial vineyard or tomato crop should consult the nearest Department of Agriculture office for further details.

Methods of Control

The best method of control is prevention of establishment, which means keeping disturbance of the bush to an absolute minimum.

Weeds often invade in small numbers and remain at low abundance for quite a time before increasing rapidly, often after a disturbance event. The best time to control them is as soon as possible after invasion when there are only a few plants to deal with. If they are allowed to develop into a major infestation, control will be much more difficult.

Once weeds have become established, there are several methods of control. These

can be classified broadly under the headings:

- physical
- natural suppression
- biological
- chemical.

Whatever method is used, start controlling weeds in the least affected areas first, working outwards towards the more degraded sections. This allows the native plants still present to regenerate and grow in the gaps left by the weeds.[6] If you judge that there are not enough mature plants to provide seed, then appropriate seed can be introduced to the site (see chapter 10).

Remember - one year's seeding - seven years' weeding!

Physical Methods

These could involve manual hand-pulling as well as mechanical mowing, slashing, cultivating or scalping.

Manual Pulling

Hand-pulling of individual weeds could be considered in the following sets of circumstances:

- when the bush concerned is in very good condition, with only a few small and localised areas of weed invasion
- when the bush to be weeded is close to the house and frequently visited
- when the weeds to be removed are easy to remove by pulling
- when rare or endangered plants are closely associated with the weed and could be damaged by other methods
- when a weed new to the area is first detected in small numbers, to eliminate it before build-up in numbers occurs
- when there are a number of enthusiastic volunteer workers.

Hand weeding has some distinct advantages in that it can be used very selectively to remove weeds from native vegetation with the least possible disturbance and thus minimise the likelihood of re-invasion. However, it is time-consuming and labour-intensive.

The whole of the plant should be removed, including all organs of vegetative propagation such as bulbs, corms, rhizomes or tubers. Collect all seed pods or capsules. Remove everything from the site and destroy the material, for example by fire.

Manual removal was very successfully taken to its logical extremes by the Bradley sisters to control weeds in Sydney's urban bushland and is often referred to as "The Bradley Method".[7]

Mechanical Methods

Mowing or slashing are appropriate where areas are dominated by grasses and there is no admixture of desirable native species. In open areas, tractor or ATV mounted machines may be suitable but for more precise control, a hand-operated 'whipper-snipper' is useful.

Slashing is useful to minimise the fire hazard from grass fuel. It should be done before seed sets as it does not kill the weeds; indeed, it may shake off and spread the seeds. For these plants, if seed set is to be prevented, mowing would have to be repeated several times during the growing season. For example, Margaret Blight of West Dale mowed wild oats around her sandalwood trees four times during 1991.

In degraded remnant bush, slashing could be used as part of a management programme for weed control prior to regeneration by direct seeding. It is an especially valuable technique if densely tufted grasses such as African lovegrass, fountain grass (*Pennisetum setaceum*) or tambookie (*Hyparrhenia hirta*) are involved, as the dense growth of old leaves impedes the efficient penetration of herbicides.

Removing the dense tops by slashing or burning encourages fresh growth which is then more susceptible to herbicidal control.

Where there is little or no natural vegetation needing protection, very heavy grazing by stock (particularly sheep) for a short period may be a possible method of grass weed control.

While cultivation is a method of weed control which may be used in paddocks, it is not usually appropriate for bush remnants as it creates far too much disturbance and becomes an excellent seedbed for a future crop of weeds. In addition, cultivation can break up and spread vegetative parts and so disperse plants such as arum lily and various woodsorrels, including soursob (*Oxalis pes-caprae*).

However, cultivation may be valuable when preparing ground for direct seeding during a regeneration project, especially if the area has lost all the native ground layer and retained only trees (see chapter 10).

Scalping - removing or pushing aside the top layer of soil containing the weed seed bank - is a very useful technique for weed control during regeneration projects. Most tree-planting machines work on this principle, creating a weed-free furrow to decrease competition for the young seedlings. In the higher rainfall areas of the State, Main Roads has shown that scalping using a road grader is a very successful method of ground preparation prior to regeneration by direct seeding. (For further detail see chapter 10.)

Natural Suppression

This involves creating a situation in which native plants are encouraged to grow and weeds discouraged.

Three things encourage weeds: soil disturbance, an increase in nutrients and increased light.

Weeds can be suppressed by soil mulches and vigorous native competitors. Leaf litter and branches should be allowed to remain on the ground, as even a mat of dead grass can inhibit new grass germination.

Fire removes this mulch. If used to remove grass stems as a method of fuel reduction, it is a good idea to follow with chemical control and reseeding of native species into the gaps left by the weeds. Fire alone merely promotes the growth of the weeds, especially if it is used too frequently (see chapter 9).

Vigorously growing native shrubs and trees use most of the available moisture and nutrients and may suppress competition around them.

These effects are often seen on roadsides. In fact, tree roots can be a problem where they extend into crops or pasture (see page 90). Weed control through direct seeding is based on a dense, fast-growing native plant community which inhibits weed establishment.

Biological Control Methods

Most weeds are not troublesome in their own home country, as they have evolved together with other organisms that eat or compete with them, and so a balance is maintained. Arriving in Australia without their control agents, the plant becomes a problem. The technique of biological control involves the introduction of a natural predator or a disease which will destroy the weed without affecting non-target plants.

The success of the cactoblastis moth in controlling the disastrous infestation of prickly pear in Queensland is an example. Paterson's curse (*Echium plantagineum*) and blackberry (*Rubus* spp.) are other plants that have recently been subject to studies of biological control.

Despite all its good features, the large cost involved means that few environmental weeds have been subject to biological control methods, though this may change in future.

Chemical Control

Used with care, chemicals can be a very effective method of managing weeds. They should always be applied when the plant is actively growing, at a time of day when transpiration is most rapid.

The right chemical always should be used to produce the control desired. Some chemicals used in normal agricultural practice may be very useful for managing weeds in bushland, others can be very damaging. Glyphosate (for example Roundup ®) is commonly used in bush regeneration as it is reasonably safe for the operator and also is inactivated on contact with the soil. It therefore does not move through the community or linger to prevent the germination of native plants.

If there are no native plants of concern, broadacre application using a boomspray fitted to a small vehicle could be used, but in mixed vegetation a hand-operated apparatus is better. In such areas, selective herbicides which remove the weeds without harming the native plants may be used. In addition, the timing of the herbicide application can often be arranged to target the exotics only. For example, most annual grasses germinate before native seedlings.

Soil residual herbicides should not be used in any area which may contain the roots of desirable shrubs and trees. Gradual dieback due to uptake of this type of herbicide is one cause of rural tree decline. Specific methods are considered in more detail in the next section.

For details of herbicide use and action, including advice on the different products available, contact the Dept of Agriculture, the APB or other authority prior to designing any spray programme.

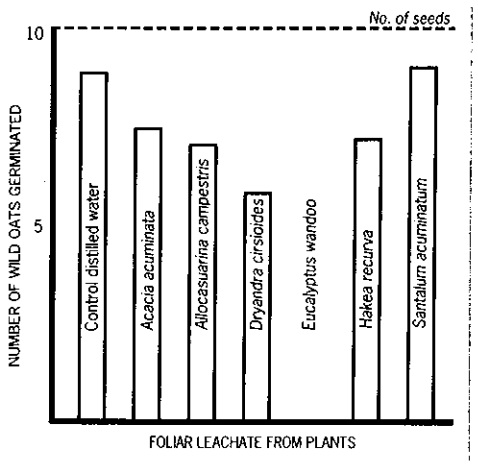
"Allelopathy" - the inhibition of one plant species by another[8]

There could be many reasons why vigorously-growing native trees and shrubs retard weed growth beneath them, including:

- competition for water
- change in soil acidity
- competition for nutrients and light
- alteration of the microclimate
- inhibiting substances produced by leaves, branches and roots.

In order to test the last possibility, CSIRO's Lyn Atkins and Richard Hobbs soaked leaves of six common plants in water to extract the juice, then used this "leachate" to germinate oats (see graph). Several of the plants had some effect, but wandoo was dramatic; there was no germination at all. Note that sandalwood does not inhibit weeds; indeed, the researchers found an increase in exotic weed establishment underneath sandalwood trees.

Some plants leaves produce substances which inhibit the growth of other plants.



Planning a Weed Control Campaign

- Define the problem:

  Are the weeds Declared Plants?

  Is there a fire hazard? (See chapter 9)

  Is native plant growth being inhibited?

  Is regeneration of native plants being hindered?

  Is the native fauna habitat degrading?

  Is the area developing an unattractive appearance?

- Identify the weed type that is causing the problem.

- Note the values that need to be protected during the weed control campaign:

  Is Declared Rare Flora present? (See chapter 5)

  Is there other native vegetation that could be harmed?

  Is there a potential land degradation hazard?

  Is there a potential hazard to other values (for example, spray drift onto crops)?

- Decide on a control strategy (see below).

- Decide what active steps will need to be taken to regenerate native plants into the spaces vacated by the weeds (see chapter 10):

  Is natural regeneration likely to be sufficient?

  Should seedlings be planted?

  Should brushing be done?

  Should direct seeding be undertaken?

Management Strategies for Specific Types of Weeds

Declared Plants must be controlled to the standard laid down by the APB (see page 78). However, the control of environmental weeds is at the discretion of the landholder.

The level to which weed control is undertaken may depend on several factors, including economics. Clearly, the cheapest option is to limit weed establishment in the first place.

From the point of view of their control in bush remnants, weeds may be divided into five types:

1. Woody weeds - trees and shrubs.
2. Herbaceous perennials - bulbs, tubers and runners, etc.
3. Perennial grasses.
4. Annual grasses.
5. Broadleaved annuals.

Preventing weed invasion

The easiest way to prevent weed invasion is to limit mechanical disturbance and nutrient addition. Therefore:

- keep disturbance of bush remnants to an absolute minimum
- do not divert drains, banks or waterways into bush remnants
- manage fertiliser application in such a way that drift into bush remnants does not occur
- plant a buffer of dense vegetation between the bush remnant and a source of windblown weed seed (see chapter 5)
- construct an interceptor ditch and bank to catch weed seed and fertiliser run-off from upslope paddocks (see chapter 5).

Limit weed establishment - prevention is better (and cheaper) than cure.

Control methods vary according to the type of weed, and are discussed in detail below.

Control of Woody Weeds

These are perennials, shrubs or trees, which are not native to the remnant and degrade its value as a conservation area by displacing native vegetation and its associated fauna.

Under conditions which favour them, plantation or ornamental tree seedlings can invade remnants and this is often seen with pines, lemon scented gums (*Eucalyptus citriodora*), and river gums. While some may blend in reasonably well, pines acidify soils and create heavy shade, to the detriment of surrounding native vegetation.

Some shrubs can also become problem weeds, especially where they are fast-growing and out-compete native shrubs. Tagasaste, and taylorina around Albany, are outstanding examples. Both were imported for production reasons - tagasaste (*Cytisus proliferus*) from the Canary Islands for fodder, and taylorina (*Psoralea pinnata*) from the Cape Region of South Africa because it produces abundant nectar for honey bees. Given appropriate climatic conditions, both naturalise well and have the potential to dominate communities.

Shrubby wattles (acacias) are a special case. Planted usually for their attractive floral display, they seed prolifically and soon spread through suitable areas. Several species such as Queensland silver wattle (*Acacia podalyriaefolia*), Cootamundra wattle (*A. baileyana*), and Sydney black wattle (*A. dealbata*) all grow well, but the most successful naturalised wattle is Australia's floral emblem, the golden wattle (*A. pycnantha*). In some areas, such as the roadsides to the east of Mount Barker, it blends in so well that it is difficult to believe that it is an introduction. Although it is tempting to consider this plant a native, as it originates in Australia, it is an exotic as far as WA is concerned. In areas whose primary management aim is nature conservation, it should be removed to allow an appropriate local native plant - often a wattle such as golden wreath wattle (*A. saligna*) - to re-establish.

Control Methods

Manually pull up or dig up the whole plant, if it is small enough.

Chemical control - apply herbicide to the whole plant at time of maximum growth - spot spray or use a wick applicator if other plants could be affected. (Recommended herbicide, glyphosate 1 part to 50 parts water. A surfactant, for example Pulse ®, may be useful.)

If the plants are large - saw off at ground level and immediately paint herbicide onto the cut stump (glyphosate 1 part to 10 parts water). Note: the treatment will not be effective unless the plant is actively growing and the herbicide is applied immediately to the cut stump.

If it is intended to let the dead tree remain standing - make oblique cuts into the bark near the base of the trunk and immediately apply herbicide (glyphosate 1 part to 1 part water). Later, herbicide (glyphosate at 1 part to 50 parts water) any coppice shoots.

In all cases, if the plant carries viable seeds, they should be removed and killed.

Control of Herbaceous Perennials

Herbaceous perennial is a term used to cover plants which die down each year and then regrow from a bulb, corm, rhizome or tuber. Ecologists use the term geophytes.

This life form is not common in native WA plants, although it is shown by many orchids, sundews and plants in the lily family such as the nancies (*Wurmbea* spp.) and milkmaids (*Burchardia* spp.). Because this is an almost empty niche in the WA environment, exotic plants brought in,

usually because of their beauty as garden ornamentals, have had no trouble fitting in. Even an orchid from South Africa, *Monadenia bracteata*, which was first noted near Albany in 1944, is now widespread throughout the lower south-west.

A more important example, Guildford grass (*Romulaea rosea*), is ubiquitous throughout the wetter roadsides and natural areas in the south-west, and is replaced in the somewhat drier regions by thread iris (*Gynandriris setifolia*). Both are persistent and troublesome weeds that can dominate the ground layer of disturbed remnants, especially if there is any level of winter grazing by stock or rabbits which ignore their tough leaves in favour of more palatable morsels.

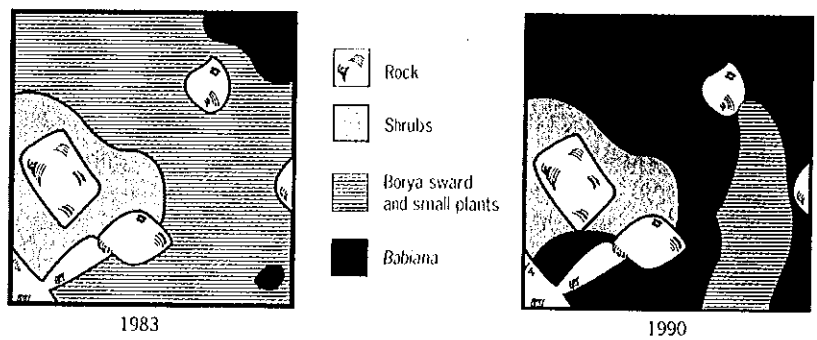
Because they have efficient methods of spreading by both seeds and vegetative organs, many bulbous plants will come to dominate natural areas if uncontrolled. Eventually they will crowd out native plants and, as they produce a lot of leaf material which dries in summer, they increase the fire hazard. Baboon flowers (*Babiana* spp.) are beginning to do this in some areas of the Darling Range, while watsonias are notorious for choking swamps and the banks of freshwater creeks. Freesias continue to expand their range, and are now beginning to become conspicuous in the south-eastern wheatbelt.

A plant which is already a severe environmental weed in South Australia and is beginning to make itself felt here is bridle creeper (*Asparagus asparagoides*). This plant is a twiner, arising from a mat of fleshy tubers just below the soil surface. It scrambles up and over shrubs, preventing light from reaching their leaves and severely limiting their vigour, if not killing them outright. The fleshy fruits are eaten by birds which spread the seeds in their droppings.

Invasion of bush on Gooseberry Hill by baboon flowers[9]

South African baboon flowers (*Babiana* spp.) are spreading relentlessly through the bush on Gooseberry Hill, Kalamunda. They produce numerous light seeds and many small corms on the stem, and although soil disturbance gives them an advantage, it is not necessary for their establishment. The diagrams below show the same one square metre plot of land seven years apart.

It is much easier to control weeds when they are few in number.



This plant will severely degrade a remnant if it is permitted to persist.

A management plan for the control of bridle creeper appears in the appendix.

Control Methods

Manually pull or dig up the whole plant. Because these plants can reproduce vegetatively from underground parts, it is essential that all bits are removed. Simply pulling up the plants and dropping them *in situ* is not enough - they will grow again.

A very effective time to pull, if the weather obliges, is immediately following heavy early summer rain, i.e. in December, as there still will be enough of the aerial parts left to get a good pull, and the current crop of roots will have died, loosening the plant's hold on the soil. However, if the plant produces bulbils, as does the cape tulip, these will be left behind for next year. Collect all the bits.

Remove and destroy the plants, possibly by fire. Using a sieve to sift the soil may be useful in reducing the amount of material to be carried away and also may make the burning of the plant material more effective.

Chemical control. Apply herbicide at the time of active growth, usually just prior to flowering. Apply with a spot spray, a wick applicator or, for the most precise control, a watsonia glove. (Recommended herbicide - glyphosate, 1 part to 50 parts water. A surfactant, for example Pulse®, may increase effectiveness.)

Spraying may need to be repeated for two or more years until all dormant corms have germinated and been dealt with.

Avoid damaging shrubs that are supporting climbing species, such as bridle creeper. Pull weeds away from native shrubs and flatten them prior to spraying.

Control of Perennial Grasses

Perennial grasses form tussocks or mats and may be either summer or winter growing. They are very efficient at extracting water and nutrients, competing strongly with established native plants and severely impeding seedling regeneration. In addition they produce an annual crop of highly flammable fuel, and greatly increase the fire hazard of remnants where they occur.

Perennial veldt grass will invade sandy soils - very rapidly if there is any sort of disturbance, such as stock or vehicle movement. It grows and flowers during winter and spring and is a major weed of banksia woodlands, displacing native annuals, hindering seedling regeneration and increasing the fire hazard. In wetter regions of the State various canary grasses (*Phalaris* spp.) can also be a problem.

Many grasses have their main growing period during summer and thus control actions have to be taken at that time. The tussock grasses, African love grass, feathertop (*Pennisetum villosum*), fountain

Figure 6.1 Watsonia glove

grass, giant reed (*Arundo donax*), pampas grass (*Cortaderia selloana*), Natal redtop (*Rhynchelytrum repens*), Rhodes grass (*Chloris gayana*), and tambookie, all fit into this category, as do the mat grasses, couch (*Cynodon dactylon*), and kikuyu (*Pennisetum clandestinum*). They have light seeds, easily transported by wind, or by stock and vehicle movement.

Control Methods

Grass control should always be done prior to seed-head formation to prevent the control action actively spreading the grass.

Manually pull or dig up the whole plant. For plants with extensive root systems, such as African love grass, this can cause large soil disturbance and so create an excellent seed-bed for future weed establishment.

Chemical control. Tussock grasses are sometimes difficult to control chemically, as their growing points - which are most susceptible to the chemical - are protected by the dense mass of dead stems and leaves. Therefore, efficient chemical control is obtained by removing the bulk of the tussock at the start of the growing season by slashing or burning off. This forces production of regrowth which is both accessible and highly susceptible to the chemical.

For winter-growing grasses, like perennial veldt grass, apply chemical in June or July.

For summer-growing grasses, apply chemical between December and March.

Apply herbicide to the fresh, new growth when it is growing vigorously (recommended chemical - glyphosate 1 part to 100 parts water, or fluazifop, for example, Fusillade® 1 part to 100 parts water and wetter).

If the grass is growing among desirable native plants, a grass-selective herbicide can be used, for example, fluazifop. It should be applied early in the growing season when the grass is making vigorous growth, and can be sprayed over the top of most native plants - including seedlings - with no adverse effect. However, this technique affects some native grasses, cord rushes, orchids and plants of the lily family. Research into herbicide effects continues.

Control of summer-growing grasses by overspraying with fluazifop should have a minimal effect on native vegetation, as most of the plants likely to be affected will be in a period of summer dormancy at the time when the grass is growing actively, and so will not take up the herbicide. However, it would be a good idea to keep an eye on the effects of spraying from year to year to ensure native plants are not being detrimentally affected.

For winter-growing grasses, spray as soon as the grass is seen to be making vigorous growth, as this is likely to be earlier than the growth period of most native plants.

For dense tussocks, the application is likely to have to be repeated at least twice unless slashing or burning is carried out first.

Control of Annual Grasses

These grasses germinate each year from seed. Some, for example blowfly grass (*Briza maxima*), are extremely widespread but their impact on the environment is not known. Although they undoubtedly compete for nutrients with native annuals such as everlastings, elimination is probably impractical as they are so widespread.

Wild oats is a different matter. This plant is very vigorous and a major competitor which will decrease the growth of other plants. Trials along a roadside in Victoria Plains have shown that the very attractive native daisy, slender podolepis (*Podolepis gracilis*), doubled in size and number of flower heads once competition from wild oats was removed.[10] Native plant regeneration from seedlings will almost certainly fail if wild oat competition is not removed. In addition, wild oats die down each year to produce a severe fire hazard,

as its dried stems are extremely flammable and very easy to ignite.

Other annual grasses that may be a problem in some situations are bromes (*Bromus* spp.), barley grass (*Hordeum* spp.), and rye-grass (*Lolium* spp.).

Control Methods

Manually pull or dig up the whole plant. This is the best method if the infestation is very small, perhaps just getting started.

Chemical control. Apply herbicide early in the growing season at the two-leaf stage.

If damage to native plants is not a problem, use glyphosate 1 part to 100 parts water.

If the annual grasses are growing among native plants, use a grass-selective herbicide, again at the two-leaf stage (recommended herbicide - fluazifop 1 part to 100 parts water and wetter).

Control of Broadleaved Annuals

The weeds of remnant vegetation are often the same as those of the adjacent paddocks, flatweed (*Hypochaeris glabra*), capeweed, thistles, stinkwort (*Dittrichia graveolens*), Paterson's curse, radish and turnip (*Brassica* spp.) for example. However, plants valued in a paddock, such as lupins and clover, can become weeds in a remnant.

Again, these plants compete for nutrients, inhibit native annuals, hinder regeneration of seedlings and may become a fire hazard in summer.

The most important of these weeds, from a nature conservation point of view, are those with broad, ground-hugging rosettes of leaves and those that put nitrogen into the soil. Flatweed and Paterson's curse, for example, form very broad rosettes which effectively eliminate competition and so maximise space available for the weed. Everlastings are soon displaced by this mechanism. Clovers and lupins release an annual load of nitrogen and so help to prepare the ground for invasion by other weeds which require a high nutrient level.

Control Methods

Plants should always be controlled prior to seed set.

Manually pull or dig up the whole plant.

Chemical control. Apply herbicide in the active growing season. Use a spot spray or a wick applicator (recommended herbicide - glyphosate 1 part to 100 parts water).

Broadleaved selective herbicides exist, but these also damage native plants, so should not be used except possibly for spot application on large infestations.

Native Plants

While native plants are not a problem for management of remnant vegetation, they sometimes impinge on the management of adjoining agricultural lands. The next two sections deal with poisonous native plants and tree competition with pasture and crops.

Poison Plants

Plants have evolved many methods of defence against being eaten by herbivores, such as the stiff, spiky leaves of needlebush (*Hakea preissii*) and standback (*Hakea recurva*). Others discourage grazing by having hairs or an unpleasant taste which effectively warns off the grazing animal, but this is not always so. In some cases the plant gives no warning, yet it may contain a potent poison.

Poisonous plants are not a problem to native animals, only to domestic stock. In well-fenced, ungrazed, remnant vegetation, plants containing poisonous chemicals are part of the natural environment. Indeed, thickets of poison bushes may be vital to the survival of some native animals (see chapter 8).

Many farm remnants have been fenced to exclude stock because of the presence of these toxic plants. They can be grouped together according to the chemical which causes the toxicity.[11] Some examples are:

Fluoroacetic acid: for example, species of *Gastrolobium*, the poison peas. Various species are found throughout the south-west. All parts are poisonous at all times, but are most toxic when flowering or growing strongly.

Cyanides: for example, clover-leafed poison (*Goodia lotifolia*). These occur in the Great Southern and south coast areas. Flowering shoots are suspected of killing cattle under stress from droving.

A second example is the commonly planted tree, sugar gum. This South Australian tree is often planted in shelter belts. Young leaf growth, especially coppice shoots, are highly toxic.

Alkaloids: several weeds produce this type of toxin, including cape tulip and Paterson's curse. Cape tulip is poisonous to cattle; Paterson's curse is mostly a problem for horses.

Toxic substance unknown: in some cases, plants have been linked with animal deaths, but the toxic agent is not known, for example, poison sedge (*Schoenus asperocarpus*) which occurs in slight depressions on sandplain, both northern sandplains and south coast. New growth is toxic, especially after burning.

Another example is blind grass (*Stypandra imbricata*) which is found on granite outcrops. Populations south of Perth appear to be toxic when young shoots appear after rain. North of Perth the plants do not appear to be toxic.[12]

All the plants listed on the next page contain fluroacetic acid, but some are more toxic than others due to the concentration of the poison or the availability of the plant.

Management of Poison Plants

The toxicity of a particular plant depends on several factors, including the general health of the stock which eats it. Toxicity is greatest when:

- the plants are rapidly growing - for example, regrowth after a fire or summer rain
- the plants are moist with dew or rain
- the stock are hungry
- the stock are stressed by mustering, shearing, etc.

Many toxic plants are vital parts of the natural ecosystem. The peas, for example, are an important part of the natural nitrogen cycle, and could be encouraged to return to areas where they were formerly present - as bullock poison returned to mallet hills - as long as grazing stock are securely excluded. In wandoo country, thickets of box poison are excellent habitat for tammar wallabies, woylies and mallee fowl.

If grazing will be permitted in the future, control of the poison peas should continue. The best method is hand pulling. The less poisonous plants, such as blind grass, may be lightly grazed during their dormant period. (Poison plants that are also Declared Rare Flora may only be taken with the permission of the Minister for the Environment.)

Note the case of sugar gum, a useful tree often planted for shade and shelter. Grazing can be permitted around it, providing young leaf growth is out of reach of stock.

Tree Competition with Crops

A problem where mature trees occur in remnants is that they will compete with the crop for water and nutrients. They will also actively suppress crop and pasture growth beneath their crowns.

WA's Poisonous Gastrolobium species

Some plants in the genus *Gastrolobium* accumulate fluoroacetate, similar to the commercial poison, 1080, which is extremely toxic to stock. A recent paper reviews the taxonomy of this group and what is known of the toxicity*. Below is a list of the species that are known to, or possibly, contain fluoroacetate.

Species known to contain fluoroacetate:

G. bennettsianum	Cluster poison
G. bilobum	Heart-leaf poison
G. brevipes	-
G. brownii	-
G. callistachys	Rock poison
G. calycinum	York Road poison
G. crassifolium	Thick-leaf poison
G. crispatum	-
G. cuneatum	River poison
G. floribundum	Wodjil poison
G. glaucum	Spike poison
G. grandiflorum	Wallflower poison
G. graniticum	Granite poison
G. hamulosum	Hook-point poison
G. laytonii	Breelya (kite-leaved poison)
G. microcarpum	Sandplain poison
G. oxyloboides	Champion Bay poison
G. parviflorum	Box poison
G. parvifolium	Berry poison
G. polystachyum	Horned poison (Hill River poison)
G. pycnostachyum	Round-leaf poison
G. racemosum	Net-leaf poison
G. reflexum	-
G. rigidum	Rigid-leaf poison
G. rotundifolium	Gilbernine poison
G. spectabile	Roe's poison
G. spinosum	Prickly poison
G. stenophyllum	Narrow-leaf poison
G. tetregonophyllum	Brother-brother
G. tomentosum	Woolly poison
G. trilobum	Bullock poison
G. velutinum	Stirling Range poison
G. villosum	Crinkle-leaf poison

The following species have not been tested for fluoroacetate but, given their close relationship to toxic species, probably do contain it.

G. discolor	-
G. euryphyllum	-
G. hians	-
G. melanocarpum	-
G. muscarum	-
G. ovalifolium	Runner poison
G. tergiversum	-
G. wonganensis	Wongan poison

The presence of fluoroacetate in other species of Gastrolobium is unknown.

* Chandler, G.T., Crisp, M.D., Cayzer, L.W. and Bayer, R.J. 2003. Monograph of Gastrolobium (Fabaceae: Mirbelieae). Australian Systematic Botany 15, 619-739.

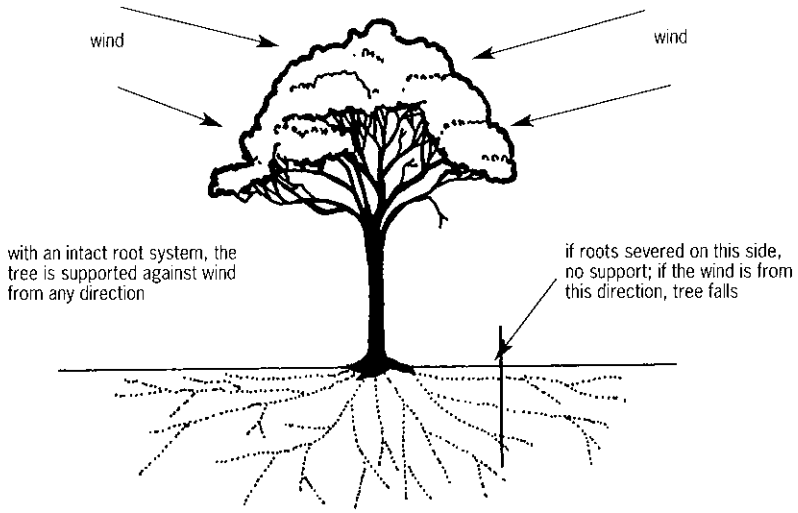
Wilf Henderson of Salmon Gums believes he has the answer to the problem of tree/crop competition. On his property, 20 m wide strips of remnant goldfields woodland (consisting of salmon gum, gimlets, dundas blackbutt (*Eucalyptus dundasii*), various mallees and shrubs) have been left around paddocks. It is considered essential to retain these as windbreaks. However, in this marginal country at the edge of the wheatbelt, competition with the crop leads to reduction in yield as the trees have surface roots extending out to at least the height of their crown.

Wilf has found that ripping one metre in depth, five to six metres out from the trees, every two years, controls his problem. It is important not to rip too close to the trees, as they would be then subject to windthrow, so the ripping is done on the edge of the graded firebreak/access track which has been created around every paddock. Also, if larger tree roots are damaged, then trees may be killed. However, in Wilf's case, tree growth is not impaired; on the contrary, the trees show extra vigour, perhaps because the ripline increases water penetration and new roots form where the moisture is retained at depth.

This compromise has retained the benefits of the windbreak while minimising its adverse effects.

Note that ripping too close to a tree or around paddock trees, or on both sides of narrow remnant strips, would almost certainly lead to windthrow.

Figure 6.2 The effect of ripping on the stability of isolated trees

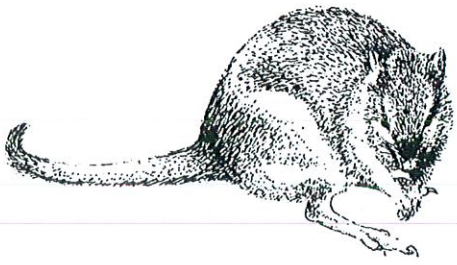


7 Principles of Native Fauna Management

- Resources
- Mates
- Predators and parasites
- Natural and other disturbances
- Role of fauna in essential functions
- Planning fauna management
- First aid for orphaned or injured animals

Note also

Problem animals: Chapter 8
Fire and animals: Chapter 9
(Parts of chapter only)



Woylie

No matter whether you are a farmer, zoo-keeper, or remnant owner, if you manage animals you must consider four aspects of their environment. These are:

- **Resources:** including food, space and shelter. These are essential for survival and affect the remaining factors.
- **Mates:** while individual animals can survive without a mate, animal populations must reproduce to persist. Sexual reproduction is usual in the animal kingdom. While there are interesting exceptions, including "virgin" birth in some lizards and self-fertilisation in some worms, such cases are not common and generally apply in special circumstances. Managers can create the resources which allow animals to meet, but they can't make them mate. The disdain with which some zoo animals treat their prospective partners after being flown hundreds of kilometres is eloquent testimony to this fact!
- **Predators and disease:** humans are one of the few Australian animals without predators. In contrast, the daily life of most animals includes the constant threat of being eaten, and sometimes predators are the final step to extinction. Disease, however, is the leveller for all animals - it is a threat which no animal escapes and against which even humans have achieved limited protection. Food and shelter are fundamental for protection from both predators and disease.
- **Natural disasters and other gross changes in the physical environment:** these are usually climate-related and include flood, drought, temperature extremes, fires, and salinisation of surface soils and water. Again, the fundamental

resources of food, shelter and space generally decide how well animals survive natural disasters and physical changes in the environment.

Being animals, humans have no trouble understanding these four issues. In common with other animals we spend most of our lives seeking the first two and trying to avoid the last two. In fact, we sometimes understand these issues so well from our viewpoint that we have trouble seeing it from that of other animals.

Resources of food, shelter and space are crucial in deciding whether or not animals survive, and to a large extent other issues are dependent on these. If resources are adequate, then animal populations will successfully reproduce and persist despite predators, disease, natural disasters and competition from other animals wanting the same resources.

The manager of native fauna, just like any stock manager, spends most time protecting and improving resources (see figure 7.1), and these are the major focus of this chapter.

Where environments are dramatically changing - for example, where salinisation is occurring or a new predator has been introduced - then native animals may decline to extinction unless managers intervene.

Thus the challenges for those managing native animals are to:

- ensure that there are sufficient resources to allow animal populations to persist. The more a manager knows about the animals, the better this will be done
- minimise the effects of new environmental factors, such as exotic predators.

In meeting these challenges for native fauna, managers will find it cheaper, and more effective in the long term, to maintain as natural a system as possible.

Resources

Food, Water and Oxygen

Food, water and oxygen are each essential for life. Their availability varies considerably, and this has an important influence on the survival, and thus management, of animals.

Foods: These include the fats, carbohydrates, proteins and minerals, which are essential for energy and building or maintaining bodies. It is important to remember that there are many ways of getting these important foods and that the needs of different animals vary markedly.

While oxygen and water are needed by all animals, the types of solid foods favoured vary considerably. A carnivore like the chuditch will not survive as a vegetarian, numbats depend for their survival on termites, while wasps which parasitise a particular insect become extinct if their host is not available, and so on.

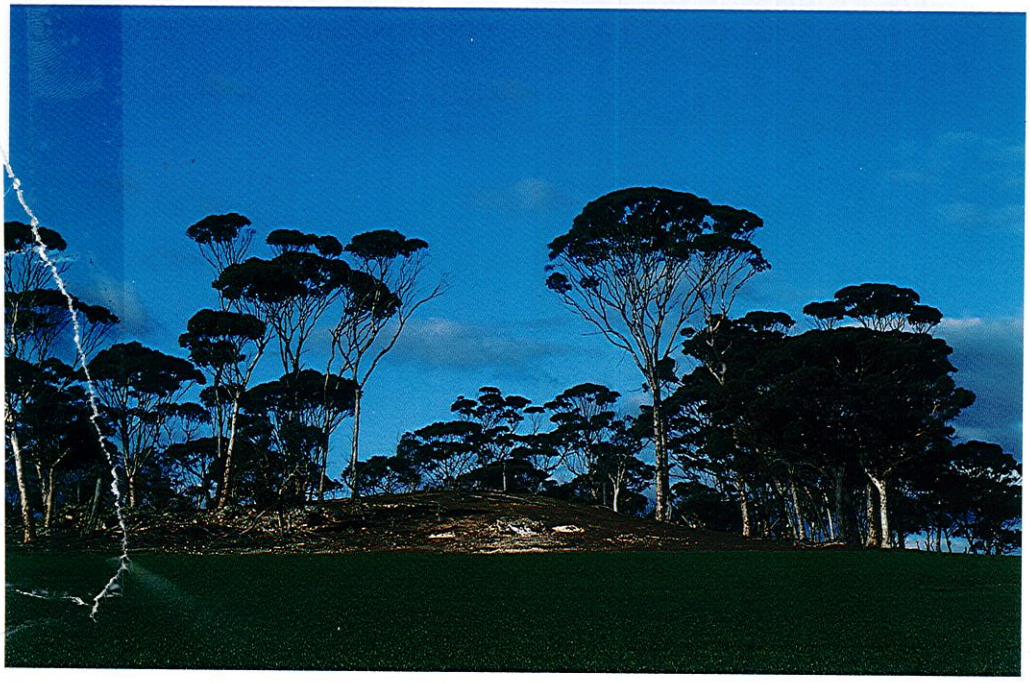
Consequently, a principle for managing native fauna is to ensure that a range of foods are available to supply the individual needs of animals. If the essential food types for a particular animal are not available, then it will not be able to survive.

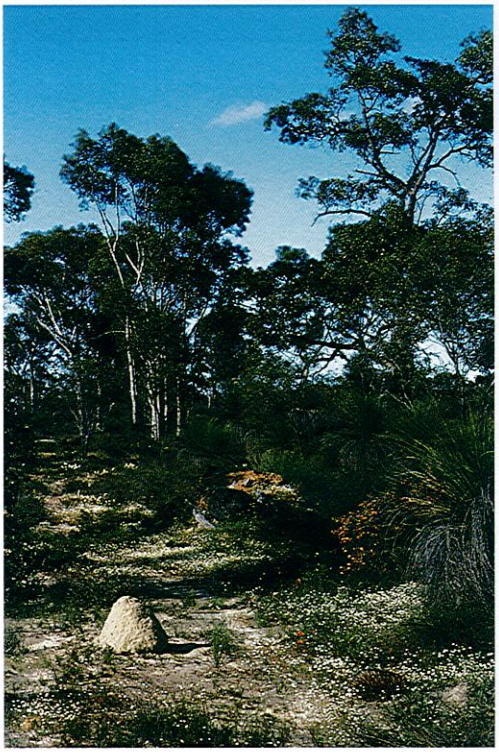
Water: Water is essential to life - humans can live for a considerable time without solid foods, but not without water. Because humans drink surface water, we tend to forget that many other animals get enough water in their food or as a by-product of converting solid foods for energy. Many animals adapted to arid areas have much more efficient kidneys than we do, produce more concentrated urine, and therefore need less water irrespective of its source. In a region where an extended summer drought is the norm, there is little surface freshwater, and severe droughts and temperature extremes occur, it is not surprising that lack of water often limits

Above: *When spraying, ensure that protective clothing is worn, as specified on the label.*

Right: *Fire can be used to remove dead weed growth and bare the soil prior to direct seeding.*

Below: *Bullock poison would formerly have covered this knoll, preventing soil erosion and providing food and shelter for native animals. If it were securely fenced against stock, this and other shrubs could be encouraged to return.*
(Penny Hussey)





Above: *The presence of 'poison peas' (shrubs cotaining the potent toxin commonly known as 1080) has led to the secure fencing of many remnants, such as this roadside carrying York road poison, to prevent stock losses. New Norcia*

Left: *Wandoo open woodland. Bolgart.*
(Penny Hussey)

Figure 7.1 Broad comparison of work undertaken by a sheep manager and manager of bush birds (Note that lists are meant to provide examples only. Many important tasks are left out)

ASPECTS OF THE ENVIRONMENT	SHEEP MANAGER	MANAGER OF SMALLER BUSH BIRDS
RESOURCES		
Food	• Provide water points • Establish pastures with good nutritive value • Hand-feed during autumn • Control competition, e.g. rabbits	• Ensure range of vegetation types are present to provide range of food types. Perhaps burn section if necessary • Plant banksias which flower in autumn as source of food • Control competition, e.g. rabbits
Shelter	• Grow windbreaks • Revegetate patches as shelter during summer cold snaps	• Ensure dense plant cover is available for nesting • Provide perching sites
Space	• Ensure farm size is sufficient to run viable flock, including space for cropping	• Link remnants with corridors of vegetation • Ensure only part of remnant burnt at any one time
MATES	• Keep flock rams • Introduce rams during appropriate season	• Increase effective size of remnant through revegetation, therefore more animals present and more mates available
PREDATORS AND DISEASE	• Control foxes • Drench sheep against worms	• Control foxes and cats • Ensure good food available all year round to increase resistance to parasites
NATURAL "DISASTERS"	• Revegetate saline affected areas with saltbush and sheoak • Alter farm practices as necessary	• Provide corridors for recolonisation

animal numbers. Many native animals have adaptations which enable them to cope with a lack of surface water.

Oxygen: While generally abundant, situations occasionally arise where lack of oxygen limits animal survival. This applies particularly to animals living in soil or water. For example, eutrophication of waterbodies (see page 64 for details), caused by an increase in nutrients, may produce oxygen depletion and thus death of aquatic animals. There is some evidence that eutrophication of wheatbelt wetlands is increasing,[1] and this may well be an important issue for anyone managing a swamp, lake or even a farm dam.

Secondly, waterlogged soils may also be very low in oxygen, and soil fauna may drown - for example, dead earthworms are common on the surface of waterlogged soils. Because soil fauna are so important in maintaining soil structure and fertility, this should be avoided if possible. Remnants low in the landscape may be susceptible to waterlogging due to rising watertables and increased surface run-off.

Quantity and Distribution of Food and Water

A critical principle for managing native fauna is to ensure food is available in sufficient quantities to maintain viable animal populations throughout the year.

It is not enough for the right type of food to be available. It and other resources must be available in sufficient amounts to maintain a minimum, viable population of animals.

A piece of isolated bush may be too small to retain a viable population of some animals. For example, a pair of numbats require an area of about 50 hectares and cannot live outside bush.[2] These factors alone ensure that numbats have disappeared from most of the wheatbelt.

Thus a remnant may be too small for some animals to reproduce and maintain a population. In the case of the numbat, DEC's Tony Friend estimates that a population of 250 numbats may be required for long-term survival. This is the minimum viable population size of numbats and they would require some 6 000 hectares of suitable habitat to survive. It is clear why there is little point re-introducing this animal to isolated farmland remnants.

In fact, many remnants are carrying animal groups that are doomed unless positive management is undertaken. Denis Saunders of CSIRO found that, over a ten-year period, southern scrub-robins, golden whistlers and western yellow robins had disappeared from an 81-hectare reserve near Kellerberrin.[3]

Furthermore, the bigger the population of interbreeding animals, the less likely that problems with in-breeding will occur, and the greater will be the amount and type of genetic material for evolution.

While the minimum viable population size has been calculated for very few animals, the manager can greatly increase the chance of animal populations surviving by maximising useful habitat. Ways to

achieve this include regenerating degraded areas, and linking remnants with other remnants and with commercial or land conservation revegetation (see chapter 10).

Furthermore, food must be available on a year-round basis, and arranged so that animals don't have to move too far to get it. Quite simply, if you spend more energy getting food than you obtain from it, you die.

In some cases, animals are nomadic or migratory so that they can have access to the right amount and quality of food. The most obvious examples are birds. Pallid cuckoos and Horsefield's bronze-cuckoos mainly breed in the south-west but move northwards for part of the summer.[4] Caterpillars are eaten by both cuckoos so their presence during winter and spring may contribute to pest control.

Robert Lambeck of Curtin University is studying the use by honeyeaters of nectar from native plants in Durokoppin, the largest nature reserve in the Shire of Kellerberrin. Nectar provides a crucial energy source for honeyeaters. The available nectar exceeded the requirements of the honeyeaters for all the study periods except April, and at this time most birds left the remnant. The only nectar source available at this time is a small degraded patch of acorn banksia, 14 kilometres from the nature reserve. Not surprisingly, the banksia patch supports high densities of birds in April, and brown honeyeaters, white-fronted honeyeaters and red wattlebirds fly between the nature reserve and this patch. This remnant of degraded banksia, along with its road verge link to Durokoppin, appear to be crucial for the retention of some honeyeaters in the district throughout the year.

This example also shows that, just as with sheep, late autumn before the break of the season is likely to be a difficult period for native animals. In general, this is a good time to watch for stress in plants or animals.

The consequences of changing food availability is also clear from the impact of constructing farm dams in agricultural areas where surface freshwater was a scarce resource.

These dams have contributed to a dramatic increase in both numbers and range of a variety of species. Most obvious have been birds such as the galah[5] and wood duck.[6] The expansion of euro and red kangaroo numbers in pastoral areas in response to changed water and pasture availability has also been well documented.[7] These examples show how removing a limiting factor can cause problems, as these species must now be controlled in many areas.

Many of our native animals, particularly those of inland agricultural areas, will survive without surface freshwater - they get enough in their food and as a by-product of making energy. Therefore while adding permanent water to a remnant will favour some animals, care needs to be taken that this does not result in larger numbers of undesirable species.

Food Quality

It is important to maintain or improve food quality for animals. To do this it is helpful to understand the range of life cycles which animals adopt, and protection and regeneration of vegetation on fertile soils is a worthwhile management action.

In addition to type, quantity and distribution, food quality is important. While blowflies can survive quite well on nectar and similar foods, the females require a protein meal before they are able to produce eggs. Similarly, dry summer feeds can allow rabbits to thrive, but a substantial amount of green vegetation is required for them to successfully reproduce.[8] This is one of a number of reasons why rabbit control involving poisoned food is concentrated in the autumn period before the break of the season.

Not only is quality food often required for reproduction; it is undoubtedly linked to health and the ability of animals to fight diseases and parasites.

The distribution of high quality food changes across the landscape. In south-eastern Australia, research has shown that forests growing on more fertile soils carry more nutritious foliage, and it is at these sites that animals such as possums and gliders are concentrated.[9] Steve Morton of CSIRO argues that in arid areas there are a limited number of high fertility sites which provide a refuge in times of stress, such as drought.[10] He blames the loss of many native desert mammals on degradation of these crucial sites by exotic species such as the rabbit, cattle and sheep, and considers other factors such as exotic predators and changed fire regimes as secondary.

Therefore while all wandoo woodlands, for example, may seem the same to us, those on more fertile soils are likely to provide a better food resource.

Similarly, many of the habitats used by native mammals today may be marginal sites, rarely or sparingly used when the landscape was totally covered with native vegetation. Brushtail possums, for example, once used the fertile valleys but are now restricted to the less fertile slopes.

So remnants on fertile soils, if they are of sufficient size, may provide an excellent resource - they may be some of the few remaining "hot spots" of high nutrition which allow some animals to persist. Such areas should be a focus of rehabilitation.

Competition for Food

In some cases use of a food source by one animal will improve it for others. For example, grazing by wildebeest on the Serengeti plains in Africa improves the grazing for gazelles and results in a sequential pattern of grazing by different species.[11] However, animals of the same or different species frequently compete for the same resource. In extreme cases, invasion by exotics can result in the extinction of native species.[12]

Locally, the rabbit may severely compete both with native herbivores as it has in the case of the tammar,[13] and with stock such as sheep. Consequently people managing remnants need to control rabbits.

The ways in which animals share resources are enormously varied. Competition between species is minimised by the incredible array of specialised diets and feeding methods. In other cases, animals can shift to alternative food resources to avoid competition.

Within species, a common method of resource sharing is for an animal to have a territory. This is any defended area, the size of which varies depending on exactly what is being defended. While some birds only defend a nest site, others such as the superb fairy-wren, raven and Tasmanian native hen defend areas that provide food, shelter, and protective cover for all, or most, of the year.[14]

Another means for sharing resources within a species is to have different stages of the life cycle feeding on different food sources. Striking examples are found in the insect world and among amphibians where early life stages utilise quite different food types to those of adults. In the case of parasitic wasps the grubs feed on the flesh of their host, while the adults often obtain energy from nectar. This is why, where wasps parasitise pest species, it is useful to ensure the adults have nectar-producing shrubs available.

It is important to control exotic competitors for food resources, and, if necessary, consider controlling problem native animals (see chapter 8).

Shelter

Shelter provides protection from the weather and predators. As with food, type, quantity and distribution, and quality need to be understood.

Type

Table 1 gives examples of the range of shelter types and the associated animals.

The presence or absence of shelter of the right type is often crucial to the survival of animals.

Yilliminning Rock which lies to the east of Narrogin provides a good example. Near the picnic area, loose rock sheets on the surface of this granite outcrop have been removed for use as ornamental rock or broken up as entertainment. In this area, the ornate dragon lizard is completely absent. However, in more remote parts of the outcrop some rock sheets have survived and so has the lizard. This lizard is only found on granite outcrops - if all the loose rock sheets at Yilliminning Rock are removed or destroyed, then the lizard will become extinct on that rock.

Shelter Quantity and Distribution

As with food, the quantity and distribution of shelter varies across any given area, and also varies with time. While some types of shelter, such as loose bark on smooth-barked trees and leaf litter on the ground, regularly change over a 12-month period, others such as hollow logs and tree hollows may last for many years unless fire or some other disturbance removes them. Imagine how long it takes for slabs of granite to peel off to provide lizard habitat!

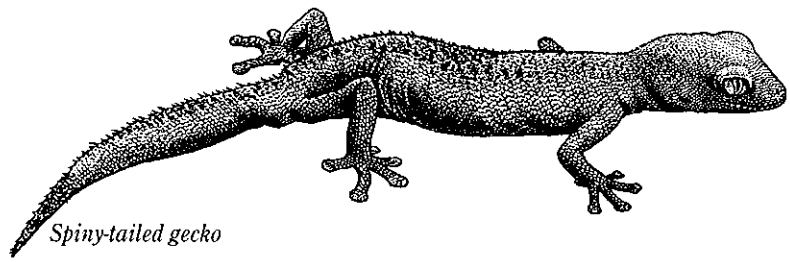
Despite the importance of shelter such as nest hollows, our understanding of how they are formed and lost is very poor, and remains a major unanswered question for remnant managers. In some cases it may prove necessary to use artificial structures to overcome a short to medium-term shortage of nesting hollows. The importance of hollows is emphasised by the fact that, for

Logs are an important habitat[15]

Patches of remnant vegetation in the wheatbelt were studied by WA Museum workers. Similar sized patches containing salmon gum, York gum, gimlet and jam with no understorey due to grazing had different numbers of reptile species - patches with logs had more species of small reptiles than patches without logs.

Logs provide shelter during the daytime for nocturnal geckoes. Some skinks live in the soft soil under logs and come out at night to feed on small insects. Logs also provide corridors to allow tree-living species to move more freely between one tree and another. Finally, the logs provide food for termites, the principal prey of some reptiles and a number of other animals including numbats and echidnas.

The greater the variety of habitats, the greater the variety of fauna.



Spiny-tailed gecko

birds alone, 11 per cent are only known to breed in tree hollows, and 18 per cent have been recorded as using them.[16]

As with food, the quantity and distribution of shelter may determine the survival of animal populations. In the case of Carnaby's cockatoo, the quantity and distribution of both food and nest hollows are critical.[17] In the wheatbelt this bird requires nest hollows in woodlands to breed, but feeds in shrublands. Loss of suitable habitat and increasing distance between woodland and shrubland remnants is threatening the survival of some populations of this cockatoo.

To improve the chances of survival for animals, increase the availability of shelter. Expanding useful habitat is one method (see chapter 10).

Shelter Quality

Shelter quality can also be an important factor. In the case of rock wallabies some populations survived despite fox predation because they lived among rock piles with deep crevices into which the wallabies could escape. The crevices also provided shelter against temperature extremes.

Competition for Shelter

Competition for shelter may threaten the survival of some animal populations in a similar way to competition for food. For example, Lindsay Millhinch has noted that 'twenty-eight' parrots are displacing mulga parrots, sacred kingfishers and kestrels from nest hollows along the Mortlock River. Further south at Woodanilling, Ray Garstone has noted the same species displacing western rosellas, purple-crowned lorikeets and smokers.

Thus the increase in 'twenty-eight' parrots due to agriculture, combined with their aggressive nesting behaviour, is a threat to less common birds.

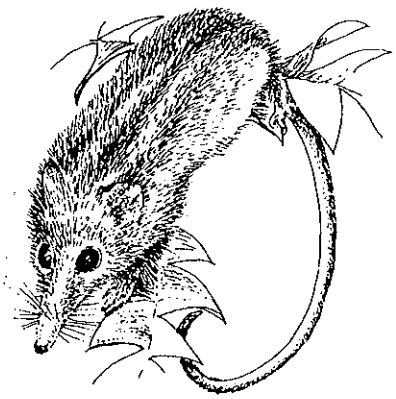
Figure 7.2 Examples of shelter used by animals

Shelter Type	Animals that Use the Shelter
Rock sheets	Reptiles, frogs, a wide range of invertebrates including spiders, insects and centipedes
Plants with loose bark	Lizards, spiders and other invertebrates
Dense shrubs	Mammals, small birds such as thornbills and fairy-wrens, and invertebrates
Hollow logs on ground	Numbats, echidnas, reptiles, a wide range of invertebrates
Hollows in trees	Bats, birds, phascogales, pygmy possums, reptiles
Rock piles	Rock wallabies, echidnas, reptiles, frogs, a wide range of invertebrates
Leaf litter	Lizards and a wide range of invertebrates
Sandy soils with bare patches	Range of specialist burrowing mammals, reptiles, frogs, and invertebrates
Branches and foliage	Safe resting sites and weather protection, particularly for birds and insects

Space

If we look at a remnant through the eyes of another animal, for example an echidna, we would find that there are areas of the remnant which:

- are very attractive. Such sections contain termites and ants suitable for eating, and satisfactory shelter, such as hollow logs or hollows in breakaway country. These areas are suitable habitat for the echidnas. (Valuable habitat)
- are attractive for echidnas, but occupied by other species, and therefore effectively not available. Perhaps the available shelter is occupied by foxes, or numbats are more efficiently taking the most available termites. (Attractive, but unavailable, habitat)
- will become suitable for echidnas, but not currently attractive. For example, in mallee country a severe fire may remove essential shelter and result in a shortage of termites and ants. Provided there is a sufficiently long period before the next fire, then such areas will again become attractive to echidnas. (Potential habitat)
- are not, and never will be, suitable for echidnas. Exposed, flat, granite rocks are of no value to echidnas, and this situation will not change inside thousands or millions of years. (Useless as habitat)



Honey possum

Looked at in this way, it can be seen that the total space of a remnant is neither available, nor necessarily useful, to each specific animal. Fortunately different animals have different requirements - the granite rock avoided by the echidna is the only suitable place for an ornate dragon lizard.

At any point in time, not only is some habitat useless for a particular species; other areas will be in an unsuitable phase of regeneration (potential habitat), or occupied by another species (attractive, but unavailable). The amount of each habitat will vary through time and it is important for a variety to be present at all times. If this is the case, then there will always be regenerating habitat reaching a stage where it is available, thus ensuring or enhancing the long-term survival of specialist animals.

Managers need to be aware that the useful area of a remnant for any one species may be quite small in relation to the total size of the remnant. Even more important, if a population of animals is to survive on a particular remnant, then there must be sufficient space available to maintain a viable population of the animals and allow for regeneration cycles.

Honey possums, for example, require a certain amount (this will vary depending on vegetation type and climate) of shrubland habitat to survive, and sufficient of this must be flowering at all times of the year. At some stage the manager of such an area will wish to burn parts of the area either to reduce a fire hazard, or to stimulate the regeneration of shrubland so that nectar production is increased in, say, five to ten years time. Depending on the particular vegetation type and the climate, there will be a post-fire period during which the burnt heath will be quite unsuitable for honey possums. The remnant manager must be careful not to burn too much of the shrubland available to honey possums at any one time, otherwise the population numbers may be driven

below the minimum viable population size and thus to local extinction.

As a principle, it is important that remnant managers understand there must be sufficient space available to provide room for animals and the regeneration of their habitat. It is important to maximise the effective remnant size - methods of doing this are discussed further in chapter 10.

Mates

If the appropriate resources are available, then animal populations will reproduce satisfactorily. It is worth remembering that the behaviour of most animals changes with reproduction and they may become more vulnerable. For example, calling and displays by territorial birds may attract cats as well as female birds - with unhappy consequences from the bird viewpoint. If frogs have to cross a busy road to reach a breeding pool, then the death rate may be high.

Again, an understanding of life histories is important for those managing native fauna. While it is impracticable to understand the requirements of all the animals living in a remnant, it is quite feasible to learn about a variety of lifestyles and this is an immense help in devising management strategies. Also the larger the remnant, the more likely that it will contain sufficient mates.

Predators and Parasites

As with mates, the primary task for the manager is to ensure that the necessary resources are available. However, where a new predator or parasite has been introduced, then control measures may become a priority.

In a natural situation, predators and prey have evolved together and exist in some sort of dynamic balance. When a new predator is introduced to the ecosystem, a whole series of changes and re-adjustments will occur which could lead to a change in the numbers of certain animals - even to their extinction. The introduction of the fox and cat into Australia is forcing such a readjustment. If we wish to preserve our small to medium-sized native mammals, it is essential to control introduced predators (see chapter 8).

Even in the case of the fox and the cat, if sufficient resources were still available in the south-west their introduction would be less of a problem. However, their introduction in combination with widespread clearing and fragmentation of habitat, including the most fertile areas, has greatly threatened the survival of many native animals.

The introduction of exotic predators and parasites (including diseases) could be catastrophic for both wildlife and agriculture. Maintaining vigilant and effective import restrictions is crucial for all land managers.

Natural and Other Disturbances

Plants and animals of the inland south-west are accustomed to surviving natural disturbances. Droughts, floods, fires, cyclones and climate changes have all occurred, causing dramatic changes in the structure and composition of habitats. This has caused species to come and go and the distribution of plants and animals to expand and contract in a dynamic process.

The scale of disturbance varies greatly from localised flooding to widespread and severe droughts, with a corresponding severity of effect upon the natural communities. At the small scale, a new mini-habitat is created which colonising animals could move into relatively easily. A large-scale event could result in particular species vacating huge areas, or leaving scattered breeding individuals in a few favoured sites. The survivors, plus immigrants, provide the basis for re-establishing populations.

Prior to European settlement, a mosaic of

vegetation communities in different stages of growth would have been created by climate, topography, soil, and disturbances. Fauna could move freely from one area to another, utilising needed resource. Many animals require this type of mosaic habitat.

Again, the role of the manager is to maximise the resources available to animals so that they can survive natural events such as flood and fire. Means of doing this have been discussed in this chapter; there are further suggestions in chapter 10.

Role of Fauna in Essential Functions

Animals play many important roles in helping ecosystems to function. Examples of just a few include:

- Maintaining soil fertility and structure. Many soil animals, such as termites, ants and earthworms, are crucial to this process.
- Pollinating plants. Many plants cannot set seed without animals pollinating them (see for example the case of the slipper orchid in chapter 5).
- Dispersing seed. Many plants rely on animals for seed dispersal, for example the role of the emu in spreading large seeds such as sandalwood.
- Recycling nutrients. Many plants need the faeces and other waste products of animals as an important source of nutrients.

These and the many other ecosystem functions performed by animals are very important to the health of remnant vegetation. Maintaining as many animal species as possible on each remnant is desirable as, if one group should become locally extinct,

Fox control benefits native mammals[18]

DEC research scientist Jack Kinnear has studied the effect of baiting for fox control on the populations of native mammals in a number of nature reserves. Some of his results from Tutanning Nature Reserve are shown below.

Predator control does not eliminate fox predation, but it reduces it to a level where some young animals are able to survive and reproduce, so the population can grow.

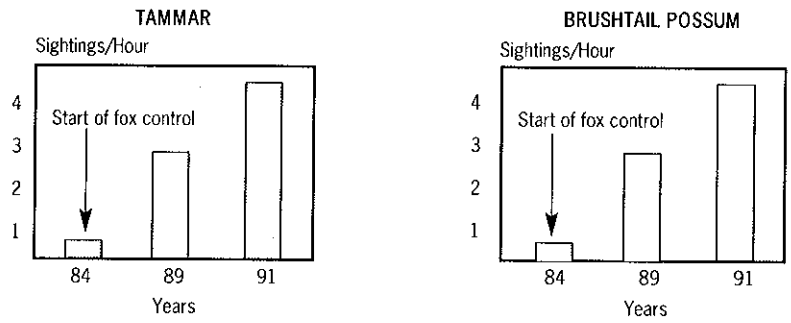


Figure 7.3 Numbers of tammars and brushtail possums sighted before and after fox control at Tutanning Nature Reserve

another group will then be available to take over their function. For example, honeyeaters may play an important role in pollination, but their numbers will undoubtedly decline in some areas. In this case there may be a particular insect which is able to maintain this essential function.

Planning Fauna Management

It is relatively easy to plan management for a single species with a well-known life history. The interactions between it and its surroundings can be itemised, and the environment manipulated for its benefit.

It is much harder to manage a habitat for the benefit of all the species it contains, as the life histories of most animals are very poorly understood. But with planning and management a habitat can be maintained that will give a range of native fauna the maximum chance of survival.

Decide Objectives

As with all other management actions, it is important to clearly describe the objectives and then plan so as to achieve them (see chapter 3).

Some managers may aim to maintain the full suite of animals that live on a remnant, while others may prefer to manage for a specific group, for example small bush birds. This decision will affect the management needed. If animals have disappeared, there is no point in re–introducing them unless the factors causing their disappearance have been corrected. There are examples of management plans for different animals in the appendix.

Collect Information

Apart from the information listed in chapter 4, write down:

- the animals which used to live in the remnant together with possible reasons for their disappearance. This may give some guidance as to how the remnant should be managed in the future
- the resources required by the animals
- the factors which have to be controlled (if any), such as predators, or increasing salinity of a freshwater body. What actions will help?
- the management objectives - and be prepared to reassess and change them if necessary.

Plan of Action

Management which maximises the type, quantity and distribution, and quality of resources available on a remnant will favour the survival and reproduction of native animal populations.

Consider the following management strategies:

- Increase the effective size of remnants wherever possible so that the variety and quantity of food types are increased. This can be achieved by rehabilitating remnants, and expanding or linking remnants with land conservation or production corridors (see chapter 10).
- Maximise the range of food resources present when rehabilitating a remnant, or revegetating areas nearby. For example use a range of plant species which will:
  - put wood on the ground for termites and other wood-degrading plants and animals which provide a food source for others
  - produce nectar throughout the year
  - provide appropriate shelter (see figure 7.4) to attract large numbers of small fauna.
- Protect remnants from hydrological changes and nutrient enrichment, as far as practicable. This is important for remnants containing wetlands.

Figure 7.4 Resources which could be provided in a bush remnant

TYPE OF BUSH	PROVIDES	ANIMALS USING THE RESOURCE
A wide variety of trees, shrubs and ground flora, so that something is in flower all year round	pollen, insects, shelter nectar foliage: leaves and leaf litter wood and bark seeds	honeyeaters, honey possum, bees, butterflies insects, possums, tammar wallabies lizards, spiders, millipedes, insects borers, termites weevils, parrots, malleefowl
A mixture of trees, thickets and open ground	shelter and a variety of foraging sites	growth of the plants, the food and shelter they provide and the spaces between them will determine the animals that can exist there
An undisturbed layer of soil litter, consisting of leaves, twigs and native animal droppings	humus formation and nutrient cycling, food and shelter for soil fauna and flora, promotes infiltration of rainwater	earthworms, beetles, centipedes, ants, termites - food for dunnarts, mardos, chuditch, echidnas, numbats
Habitat trees with holes and hollows of various sizes	shelter for nest and den sites	phascogales, possums, bats, goannas and a range of birds including ducks, owls, parrots
Fallen trees, partly uprooted stumps and hollow logs	shelter, food for termites and fungi	food supply for termite-eating animals - numbats, echidnas - shelter and den sites used also by chuditch, dunnarts, carpet pythons
Tumbled boulders or rock outcrops	shelter and den sites	provides shelter for echidnas, rock wallabies, euros, chuditch, dragons, geckos
A bank of exposed soil	burrow sites	rainbow birds, white-backed swallows, pardalotes, Gould's goanna
A range of new habitats. For example, create a wetland where there is none, a woodland near shrublands, and so on	completely new food and shelter resources	
Nesting boxes	specialist shelter and nesting sites for hollow users when these are scarce or not available	bats, water birds, parrots, reptiles
Drinking water provided	fresh drinking water favours some animals, but note that this will also encourage weedy species	kangaroos, galahs, zebra finches, honeyeaters

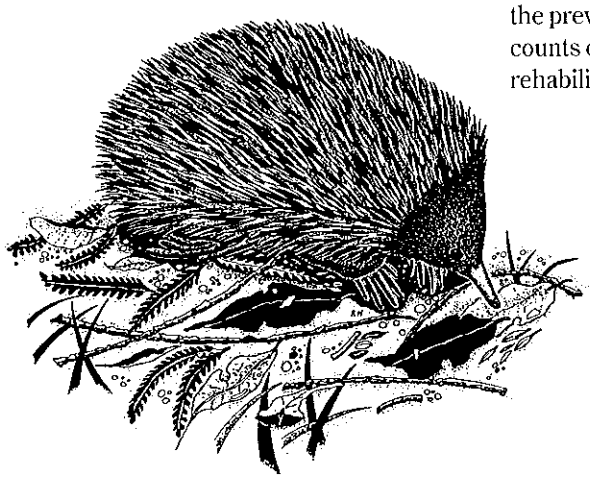
- Find out as much as practicable about the life histories of the animals being managed, and ensure that the resources they require are available in sufficient quantity and quality.
- Link feeding areas with corridors as many animals require access to specialised food resources. This is particularly important for those animals which rarely or never cross open areas (see chapter 10).
- Ensure that any disturbance regime is not too frequent. In some cases, management action involving disturbances, such as fire, may be necessary to keep food sources at a sufficient level for animals to prosper (for example flowering plants for nectar feeders). If the remnant is large enough it should exist in various stages of post-disturbance regeneration. Each stage provides different resources.
- Providing supplementary food supplies, such as water or feed during drought, should not be necessary.
- Consider regenerating (see chapter 10) fertile sites, such as grazed woodlands of York gum and red morrel, as they may be very productive for native animals
- Control exotic animals which are competing with native animals for resources.
- Control exotic plants. It is likely that these are displacing native plants, which are an important food resource for native animals.
- Control numbers of native animals, such as grey kangaroos, if they are detrimentally affecting the remnant for other native animals.

If little is known concerning the animals living on a remnant, the best management actions in the short term are to:

- exclude domestic stock
- control exotic animals and plants
- restore the natural hydrological balance, if practicable
- rehabilitate disturbed areas
- expand the effective size of the remnant by linking it with others or revegetating adjoining land for commercial or land conservation purposes, if resources permit, and it fits with the farm plan.

Monitoring and Evaluation

Some ideas are given in chapter 3 and sample management plans may be found in the appendix. However, the actions given in the previous section can be monitored by counts of exotic animals and plants, speed of rehabilitation, and photographs.



First Aid for Orphaned or Injured Animals

Looking after wildlife is a specialised skill, but some things can be done while seeking further help.[19] Ring your local DEC office for advice.

Shock is a big killer. Handling of wild animals by humans - no matter with what good intentions - can cause traumatic shock. Orphaned or injured animals should be kept calm and quiet in an enclosed container, and handled as little as possible.

- Do not feed or give liquid without first seeking advice. Incorrect techniques or wrong food could cause death.
- Do not attempt to splint a broken limb or wing. Keep the animal quiet to prevent further damage. If a wing break is suspected, the wing tips only may be taped together to prevent flapping. It is essential to immobilise the wings of large birds such as swans, as they can easily harm themselves by flapping while in restraint.
- Control bleeding by applying gentle but firm pressure with the fingers. If bleeding recommences, place a wad of clean material or tissue over the area and hold in place with a bandage or tape.
- Confine the animal in an appropriately sized-container with soft cloths or tissues on the bottom. Do not use cotton wool or cloths with loose cottons as the animal can become entangled in them and damage itself.
- Put the box in a quiet place away from dogs, cats and children. Keep at a comfortable temperature. For very sick animals, or young joeys, a desk lamp with a 60 watt globe could emit enough heat, or alternatively a hot water bottle well wrapped up in a towel. Do not leave in the sun, as the animal could overheat.
- Take care not to be clawed or bitten. Use a towel wrapped around the animal to immobilise it.

Looking after Orphaned Joeys

- Keep the animal warm with a lamp or a hot water bottle, as above. For older joeys, an imitation pouch can be made using a bag or an old sweater. Bedding material must be kept clean and dry as they are extremely susceptible to chills. Be careful not to expose them to drafts for the same reason.
- Feed young joeys on one rounded dessert spoon of Digestelact (available from chemists) added to 100 mL of warm water. Later they can lap a mix of one vitamin E tablet and two drops of Pentavite in one cup of cow's milk warmed to about 37 degrees Celsius. Young animals need feeding at four hourly intervals. As the joey gets older, reduce the feeds to twice daily with vitamin in one feed only. Clean drinking water should be available.

  Older joeys can be offered solid food such as green grass, rose petals, apples, carrots or bread.
- Oil very young joeys twice daily with baby oil. They need this oiling to keep their skin supple.

Looking after Injured Birds

Diets for various birds

First decide what type of bird you have. If the bird is being kept for a short period, the following diets would be useful, but they are not sufficient for long-term use.

Sugar solution for injured birds

If the bird needs fluids or is in shock, make a sugar solution from a heaped teaspoon of sugar or honey to $^1/_2$ cup of warm water. Drip carefully into the bird's beak from the side. Watch for swallowing. If there is any sign of choking, stop immediately.

Insect eaters:
Quality dog food with Chick Starter 2:1.

Nectar eaters:
One teaspoon honey to $^1/_2$ cup of water plus a heaped teaspoon of Complan or Farex.
(Note: Baby honeyeaters are fed insects by their parents, not nectar.)

Seed eaters:
Suitable sized variety of seeds and grit.
(Note: Babies can be fed a porridge mix of cereals but calcium and vitamins must be added. You will probably have to use a tube to get the food into the crop.)

Birds of prey:
Mice and/or suitably sized pieces of raw meat with a little chopped feathers, calcium and vitamins.

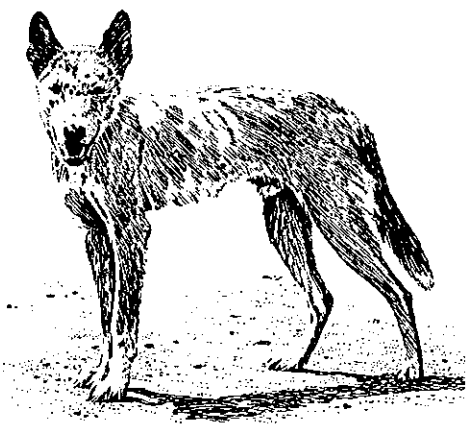
Waterbirds - grain eating:
Chickstarter crumble, wheat and chopped greens.

Waterbirds - fish eating:
Very difficult, may need force feeding.

Remember, this is all emergency treatment only. Ring DEC for longer-term help.

8 Problem Animals

- Introduced animals
- Feral animal management - individual animals
- Native animals
- Native animal management - individual animals



Dingo

Introduced Animals

Humans have brought many animals to Australia and some have gone wild. These feral animals compete with native fauna for resources, such as food and shelter, and often lead to a decline in numbers of native plants and animals. In some cases, such as the fox, predation has had an enormous impact on wildlife.

Therefore the conservation value of remnant vegetation will be increased if exotic animals are controlled and, if possible, eliminated.

The first such known introduction was the dingo. It was brought here from South-east Asia by Aboriginal people, or possibly Asian fishermen, at some time between 8 000 and 3 000 years ago and soon spread across mainland Australia. The dingo would have been in direct competition for prey with the two large marsupial carnivores, the Tasmanian tiger (*Thylacine*) and the Tasmanian devil. It was probably more efficient than either, both in hunting prowess and reproductive potential, and undoubtedly contributed to their elimination from the mainland. They survived on Tasmania because Bass Strait, which flooded 12 000 years ago, prevented dingoes reaching there.[1]

European introductions were much more varied. Not only did settlers bring with them their stock and pets but also a whole host of other creatures, sometimes deliberately introduced for sporting reasons, like the fox into Victoria, or simply to make the colonists feel more at home, like sparrows and starlings. Acclimatisation Societies were formed to pay for and foster introductions from overseas or interstate, such as that of laughing kookaburras from Victoria in 1897. While many of these failed in the wild, for

example deer in the south-west of WA, those that succeeded have frequently resulted in expensive, on-going problems for agriculture and nature conservation.

Although we tend to think of exotic animal introductions in terms of larger animals, many invasions by smaller creatures are taking place. Coastal residents from Geraldton to Perth will be familiar with the Mediterranean snail which often occurs in huge numbers, but is principally confined to cultivated land and so is not a problem in undisturbed bush. In fact, Museum researcher Shirley Slack-Smith does not feel that there has been any direct competition between introduced and native snails as they do not occupy similar niches in the bush.

Much more notable introductions have been Argentine ants, European wasps and some of the sheep blowflies. The costs to the community through losses in agriculture, control problems, and degradation of nature conservation values has been enormous.

The effect of other introduced animals, such as the rabbit and fox, is only too well documented. Competition for resources and destruction of habitat have been disastrous for both agricultural and conservation ecosystems.[2]

The moral is very clear. Exotic animals should be introduced to Australia only for compelling reasons and after considerable research has confirmed that they will have no detrimental effects. The effects of some of the better known exotics on remnant values are summarised in figure 8.1.

Legal Aspects

Declared animals must be controlled by landholders as described within the Agriculture and Related Resources Protection Act and its Regulations. These are principally concerned with the agricultural impact of the species

Figure 8.1 Effects of principal problem exotic animals on remnant vegetation

FERAL CAT

- competes with native carnivores for prey
- reduces numbers of prey species - small and medium-sized mammals, frogs, reptiles, birds and insects

FOX

- competes with native carnivores for prey
- reduces numbers of prey species - medium-sized mammals, reptiles, frogs, birds and insects

FERAL GOAT

- competes with native herbivores for food
- browsing damages many native plants
- prevents regeneration of native vegetation
- accelerates soil erosion

FERAL HONEYBEE

- may compete with native nectar-feeders, such as birds, insects, and some small mammals
- may compete with native fauna for nest sites
- decreases pollination success in some native plants

FERAL PIG

- competes with native fauna for food and habitat
- alters habitat by rooting and wallowing so that it is unsuitable for native fauna
- creates soil disturbance which leads to erosion and water pollution
- may spread *Phytophthora* dieback

RABBIT

- competes with native herbivores for food and habitat
- grazing damages many native plants
- prevents regeneration of native vegetation
- heavy grazing pressure can lead to soil erosion
- warren construction destroys plants
- warren construction and dung piles provide sites for weed invasion

Above: *In many areas of WA, especially on sandplain, roadverges are practically the only remnant vegetation remaining, and they are gradually degrading. Wubin.*

Right*: This fungus, a bolete, forms a mycorrhizal association with the surrounding plants, to their mutual benefit. It has been dug up and partly eaten by a woylie, which will spread the spores in its droppings. Dryandra.*

Below right*: Shooting can help reduce fox numbers. Note the left-hand animal - a tabby cat. Ongerup.* *(Penny Hussey)*

Case study: Revegetation

When undertaking revegetation, it makes sense to plan the project in detail.

For example, breakaway revegetation for Kit and Eileen Leake, Kellerberrin

- **Landscape goal:** to increase the amount of effective habitat to conserve existing resident flora and fauna in the catchment and improve sustainability of land use.
- **Nature conservation goals:** to increase the size of the remnant and increase the corridor width between the nature reserves
- **Sustainable agriculture goals:** to eliminate surface water runoff from above the breakaway and to increase use of annual rainfall in a high recharge area.

For more detail, see: www.dec.gov.au/programs/savings/saving-our-species/habitat-for-natureconservation/revegetation.html

Site of Revegetation

NOT TO SCALE

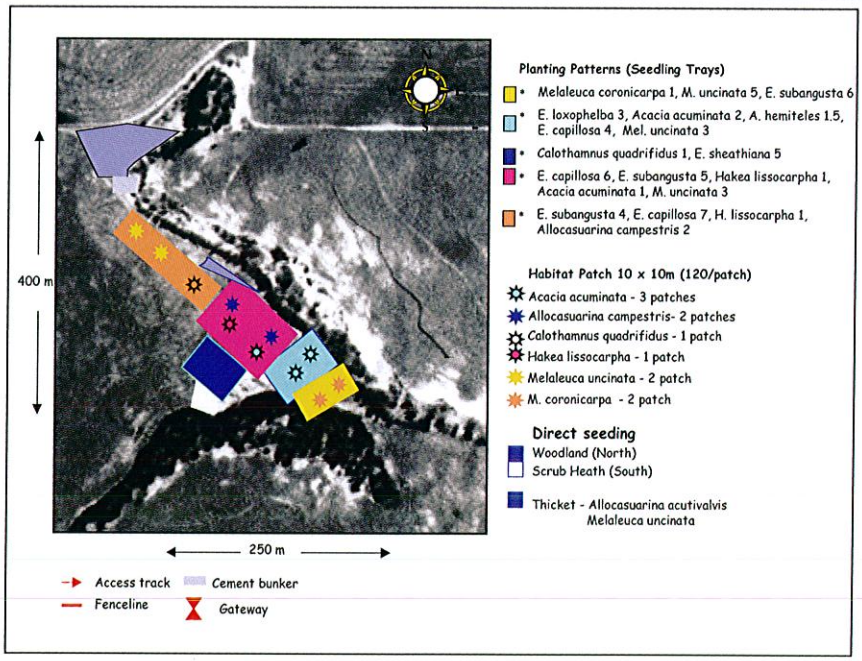


Figure 3. Planting patterns for the breakaway revegetation design, (60 seedlings per tray).

agricultural impact of the species concerned.

The Agriculture Protection Board (APB) administers the Act State-wide and advises the Government on ways to safeguard agriculture by control of problem organisms. The APB has divided the State into 11 Zone Control Authorities, most of which have Regional Advisory Committees, consisting of representatives from local shires and producers. Policies for each zone take into account the views of these representatives.

Animals considered to be a threat to agriculture can be gazetted by the APB as Declared Animals under a number of different categories which deal with:

- introduction of animals to WA or to areas where they do not already exist
- control of animals which are already established or which threaten to become established
- keeping of Declared Animals
- management of native species considered to be pests to agriculture.

Landholders bear the full responsibility and cost of controlling Declared Animals on their land. They may undertake that control personally, or may contract the APB or a private contractor.

Note that not all exotic animals are dealt with in the Agriculture and Related Resources Protection Act and Regulations - only those which threaten agriculture.

Summary of Control Methods

Shooting

Shooting is a useful method of controlling exotic animals, for example as part of a campaign to eradicate rabbits, cats or foxes. It is also used in commercial programmes for controlling kangaroos.

Codes of Practice for humane shooting exist and it is recommended that they be followed. They state that animals can experience pain and distress and therefore shooters should always aim for a clean, instantaneous kill. Head or heart shots are recommended. If an animal is only wounded, the shooter should immediately locate and destroy it so as to prevent prolonged suffering.

There are numerous regulations covering the use of firearms and it is the responsibility of all firearm users to ensure that they are correctly licensed and are complying with all appropriate regulations, including safety procedures.

Contact your local Police Station or the Firearms Branch of the Police Department for further information.

Poisoning

The use of poisons in WA is controlled under the Health Act by the Health (Pesticides) Regulations and also under some regulations of the Agriculture and Related Resources Protection Act. Poisons should always be used with extreme care and according to the label instructions. The label is in fact a legal document which defines what the pesticide may be used for and in what way. Any deviation from label instructions would, unless it had received specific approval from the Health Department, be against the law.

Baits to control dingoes, wild dogs, foxes or feral cats are also extremely toxic to domestic dogs and cats. Regulations under the Agriculture and Related Resources Protection Act control the use of strychnine baits in built-up areas, special rural zones and adjacent to roads, reserves or public places. These include:

- written notice to be given 24 hours in advance to all occupiers of adjoining land and to the Local Government Authority
- warning notices to be prominently displayed

- no baits to be laid within 20 metres of roads, reserves and public places
- baits to be secured or buried.

Consult the APB for detailed, up-to-date advice.

While a range of poisons, including strychnine, pindone and 1080 are used in control of problem animals, only 1080 is acceptable in remnant vegetation where protection of wildlife is an objective. This is because while most native animals can tolerate 1080, they are susceptible to strychnine and pindone.

1080

Sodium monofluoroacetate, better known as 1080, is one of the most toxic substances known. Most birds and mammals are sensitive to it, including humans. However, in WA 1080 is a very convenient poison to use to control exotic animals, because native animals have some tolerance to it, while introduced animals do not. Poison baits can be designed that will kill the exotics but leave native fauna unaffected.

1080 is absorbed through the lining of the intestine and carried to the cells, where it blocks the Krebs Cycle, a major pathway for releasing energy from food. This disrupts the normal activity of cells, causing severe effects on the heart or the central nervous system. Herbivores usually develop heart problems, carnivores nervous system disorders and omnivores may show both. Symptoms do not occur immediately after eating the poison, but death usually occurs within 24 hours. This delay means that a poisoned animal can move quite a distance before succumbing.

Sub-lethal doses of 1080 may affect reproductive potential as the substance damages the testes, reduces sperm production, and can lower the levels of

York Road poison

reproductive hormones. Little is known about the importance of these effects.

There is no effective antidote to 1080; therefore it must be used extremely carefully.

In WA some plants (the poison peas (*Gastrolobium* spp; see chapter 6) manufacture a related substance - fluoroacetic acid - presumably as a defence against herbivores. The substance is concentrated in the parts most likely to be eaten: the flowers, seeds and young leaves. Fortunately for inhabitants of WA, micro-organisms living in the soil deactivate this very toxic substance, otherwise this would be a very dangerous place to live! As it was, the early settlers suffered severe stock losses, especially from the notorious York Road poison *(Gastrolobium calycinum)*, which decimated flocks and herds being driven to the settlements in the Avon Valley. When farms were being developed, poison was either laboriously grubbed out or, if the growth was too dense, the area was fenced so that stock could not enter.

Many native animals in WA, which have evolved together with the poison plants over long periods of time, can tolerate high levels of 1080.[3] Thus the bronzewing pigeon, whose diet includes seeds from poison bushes such as box poison, can tolerate a very high level of 1080 in its body without showing any ill effects. A carnivore which is susceptible to the poison, such as a dog, may die after it eats a bronzewing - as early settlers discovered. However, native carnivores have evolved along with their prey and the poison plants, and so have developed varying degrees of tolerance to the poison.

Oats poisoned with 1080 have been used very successfully for many years to control rabbit numbers. Secondary poisoning as a result of this rabbit control accounts for the death of some cats and foxes.

Using 1080 to control introduced carnivores (foxes and cats) without affecting native carnivores depends upon correct bait design and location. Baits need to be attractive to the problem animals and contain a dose that will kill them, but be neither attractive nor lethal to native fauna. This is now reasonably well understood for fox control but less so for feral cats - see relevant sections below.

Exclusion Fencing

Earlier this century, rabbit-proof fences were erected across parts of the State to prevent the entry of rabbits. Only one such fence, the State Barrier Fence, intended to divert emus migrating from the pastoral regions into agricultural areas, is still maintained.

Although expensive, the erection of rabbit-proof fencing may be worthwhile if bush regeneration involving the germination of seedlings is being attempted in an area where rabbits are numerous, and it is impractical to eliminate them.

It is possible, though extremely expensive, to enclose a bush remnant with fencing that prevents the entry or exit of rabbits, cats, dogs and foxes. Control measures can then eliminate any problem animals inside the enclosure and the desirable animals are left to increase unmolested. This has been done by DEC at two nature reserves near Perth, Ellenbrook (for the western swamp tortoise), and the DEC Wildlife Research Centre at Woodvale. It is also possible to enclose an area, eliminate the problem animals and then re-introduce desirable ones. This is being tried by CSIRO and DEC at Heirisson Prong near Shark Bay. Once problems with fence materials and location have been overcome and foxes, goats and rabbits have been eliminated, banded hare-wallabies and other animals that have become rare or extinct on the adjoining mainland will be re-introduced from Bernier and Dorre Islands.

This type of fencing has also been used to contain and protect collections of animals in

open-range sanctuaries, such as Cohunu Wildlife Sanctuary near Perth and, in South Australia, John Wamsley's property, Warrawong Sanctuary. The populations of animals in such sanctuaries probably would not be viable unless the area was very large.

Feral Animal Management - Individual Animals

Note that controlling foxes and cats could lead to an increase in rabbits, while controlling rabbits alone could lead foxes to turn more to native animals or domestic stock. Therefore, it is advisable to control foxes, cats and rabbits at the same time.

Feral Cat

It is possible that domestic cats (*Felis catus*) became established in Australia before any official European settlement. Aboriginal people from central and northern Australia have suggested that cats arrived from the west, so maybe they were survivors of early Dutch shipwrecks on the north-western coast.[4] However they got here, feral cats are now plentiful throughout the continent.

Cats are solitary animals, sleeping up to 16 hours a day in a safe place such as a hollow log or burrow and hunting at night. They are carnivores, catching everything they can up to the size of a brushtail possum, but in agricultural areas the major prey is rabbit. If pressed, cats will scavenge, for example from road kills. If there is enough food the population density can get quite high and one animal per square kilometre is not uncommon. Females can breed in their first year and thereafter have two litters a year - in spring and autumn - with an average of three to five kittens. Adult cats have few enemies but most kittens die before they establish a territory for themselves.[5] Foxes may be important predators of kittens.

Cats are adaptable and opportunistic predators, and their diet varies considerably depending on where they live.[6] In the mallee in south-eastern Australia their diet consists mainly of rabbits and mice, but in the highlands small native mammals predominate. While they prefer small mammals, they will eat a very wide range of animals including centipedes, grasshoppers, beetles, spiders, lizards and birds.

Circumstantial evidence, mainly anecdotal, suggests that cats have contributed to the decline in fauna.[7] It has recently been shown that cat predation has wiped out a colony of hare-wallabies near Alice Springs.[8] Not only do they consume prey but they compete directly with marsupial carnivores, including perhaps the chuditch, a similar-sized nocturnal hunter.

Cat Control

Cats may be controlled by:

- shooting
- poisoning
- trapping.

Shooting is possible, but cats are more secretive and wary than foxes and so more difficult to control adequately in this way. It is reported that using dogs to chase and corner a cat is a very effective way to get close enough to shoot them.

Poisoning with 1080 will kill cats but since they do not usually scavenge, they are unlikely to take baits directly. However, they have been known to die through eating rabbits that have consumed 1080. If it is decided to poison for feral cats, a special application has to be made to the APB who may prepare special baits to undertake the work. Remember that baits are equally deadly to domestic cats, so they must be distributed carefully for feral cat control.

Trapping with cat traps can be very effective, especially when used at times of food scarcity such as late summer. Strongly-smelling fish-based catfood makes an excellent bait. It is a time-consuming

method as the trap should be set in the evening and visited in the early morning but it has the advantage that domestic pets and native animals can be released if trapped by mistake. Feral cats are best disposed of by shooting whilst still in the cage.

Fox

Foxes (*Vulpes vulpes*) were first imported into eastern Australia in the 1860s and by 1917 they had reached Kalgoorlie. The first record of a fox being shot in the south-west was at Donnybrook in 1929. They are now common throughout the south of the State. The fox is a very efficient predator and, besides causing agricultural losses, it has been a major contributor to the decline of medium-sized mammals in WA.

For much of the year foxes live solitary lives, roaming and hunting over several square kilometres. However, in winter they mate and co-operate to construct a den, often in an abandoned rabbit burrow, where the young will be born. A litter of four or five cubs is born in spring. By early summer the cubs are able to venture out of the den with their mother and by mid-January they disperse. Both males and females become sexually mature and breed in their first year.

Foxes usually hunt at night, but in lean times they will make daylight forays. They are omnivorous. Besides taking all sorts of live prey, they also eat fungi, berries and flowers that have a lot of nectar. They will scavenge, taking road kills or other carrion. Foxes can swim to take ducklings and tortoises, and will eat gilgies, centipedes and scorpions. They have also learnt to wait until an echidna unrolls before getting at its soft belly. Foxes have no real predators - though a wedge-tailed eagle has been seen to take a fox cub.[9] They are subject to diseases such as mange and distemper and would be carriers of rabies, if it ever reached Australia.

Foxes are very efficient predators. On the Coastal Plain they have been implicated in the decline of the very rare western swamp tortoise. This animal aestivates (sleeps) during summer in cracks in clay or under piles of fallen leaves. Those under leaves are easy prey for hungry foxes. Mammals also suffer from fox predation, and those with body weights between 33 grams and 5.5 kilograms are at particular risk where they are already in decline.[10] Even smaller animals are at risk.

WA Museum researcher John Dell believes that foxes are partly responsible for the recent decline of burrowing frogs (*Heleioporus* spp.). Immediately after the first substantial rains of the season, the males of these frogs dig breeding burrows around the highwater mark of freshwater swamps and lakes. When these are completed, they will sit inside the burrow and call to attract a mate. If all goes well, eggs will be laid in the burrow, hatch when the watertable rises and eventually the tadpoles will swim out as the burrow floods. But if foxes are around, all does not go well. Foxes locate the breeding males by their call, dig them up and eat them. Almost every burrow around many different swamps has been seen to be predated in this way. Salinity, the recent trend of dry winters, and the fox are all contributing to frog decline.

Observations such as these, and the fact that small mammals survive in large numbers on islands where there are no foxes, led researchers to believe that fox predation was contributing to the decline of native fauna. Early work by Per Christensen was followed up by Jack Kinnear, who decided to test this idea on several isolated granite outcrops with remnant vegetation south of Kellerberrin where black-footed rock-wallabies still occurred in low numbers.[11] Foxes were baited at two sites, but not at the other three. The effects were dramatic. Where fox numbers were controlled, the rock-wallaby populations greatly increased, while on the unbaited sites, two populations became extinct and the other severely declined (see figure 8.2).

Further work on fox control within Dryandra State Forest and Tutanning Nature Reserve has shown dramatic increases in the number of animals including numbats, woylies, tammar wallabies, brushtail possums and even brush wallabies. Equally significant is the observation by DEC's Tony Friend that the red-tailed phascogale, a small marsupial carnivore, has also increased in these areas. Presumably the 1080 baits used for fox control are not harming phascogales and, in addition to reduced fox predation, they are benefiting from the greater prey abundance once competition from foxes is removed.

One native animal which is still of some concern in fox baiting programmes is the chuditch. APB researchers have shown that 1080 baits pose no risk for the related northern quoll and recent research indicates that probably the chuditch is similar.[12]

Based on these results, DEC has now instituted fox control programmes with 1080 baiting in a number of conservation areas. Where chuditch are known to occur a lower concentration of 1080 is used in baits and greater attention is given to the timing of control work.

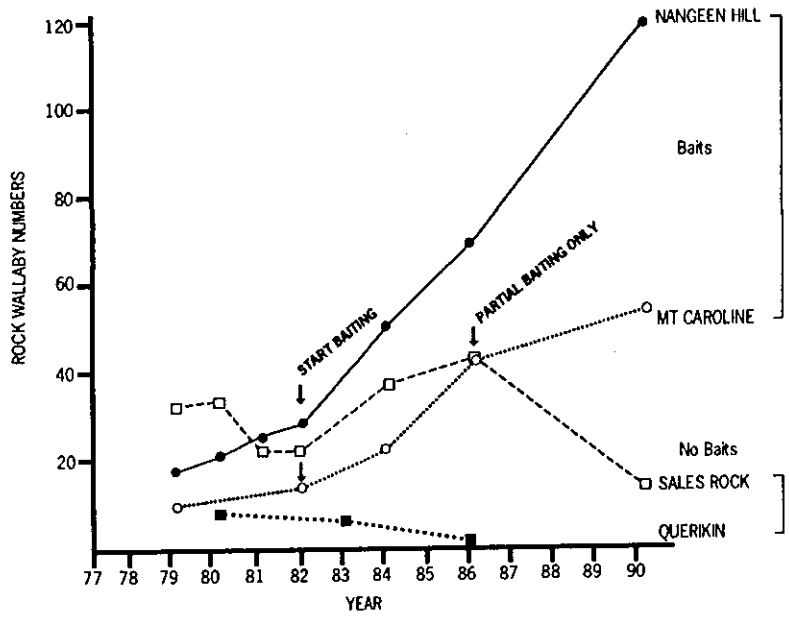
Fox Control

Foxes may be controlled by:

- shooting
- poisoning
- fumigation
- genetic methods (currently being investigated)
- exclusion fencing

Timing of fox control is important. To be effective, regular baiting or a combination of well-timed shooting and baiting should be

Figure 8.2 Effects of fox baiting on rock-wallaby numbers



used to keep fox numbers down. The most effective period is spring, when the cubs are being reared, but supplementary control at other times of the year is also necessary to remove reinvading foxes. In addition, fox control prior to autumn lambing provides a direct benefit to farm production, and baits, which are rendered ineffective by rain, last longer.

Shooting is most effective when the cubs are dispersing, from mid-January to April, as they have not yet found a new territory. Foxes travel extensively when hunting, making use of creeks, fencelines and tracks, so that shooters should work these areas first. During the day foxes camp in a place where they have a good view of the surrounding country, such as a pile of rocks in a cleared paddock, or a projecting headland of bush. Shooting would actually be more effective as a control method (though harder to do) if done during spring (August to October) when the cubs are being reared. Evidence from Victoria suggests that a determined shooting campaign will remove about one third of the population.

If a fox is shot at and escapes, it will learn from that experience and become very difficult to shoot again.[13]

Poisoning using baits can be effective, though it should be noted that any bait that will kill a fox will also kill a domestic dog, so during a baiting programme dogs should not be allowed to wander. Strychnine has been used but it kills all animals that take a bait and should only be used if it can be made "target-specific", that is, only attractive to foxes and cats. Consequently, baits using the compound 1080 are recommended for fox control.

Dried meat baits should be used. Meat should be cut into chunks weighing approximately 120 gm and taken to an APB officer for injection with 1080. The bait must then be dried to a weight of 40-50 gm, equivalent to about 60 per cent loss in weight. Note that 1080 can be rendered non-toxic by micro-organisms normally found on meat, so these baits should be used at once or stored frozen. (If storing, remember to label them very prominently.) Dried meat baits are tough and stringy and it is difficult for native carnivores, including ravens, to chew them. In addition the poison is so dispersed that, in the amounts likely to be consumed, it will not be lethal to a native carnivore.

Baits can be thrown under shrubs (to decrease the chance of birds finding them) every 100 - 200 m from a slowly moving vehicle. A better, but more labour-intensive, method would be to bury baits 50 mm deep and covered lightly with soil and leaves. This method effectively prevents carrion-eating birds such as ravens from disturbing the baits, thus cutting down on bait wastage (and loss of birds) so that they need only be laid every 500 m. Another method of preventing losses to birds is to tie the bait down with string or wire. Whichever bait distribution method is used, dragging a carcass behind the vehicle helps by laying a scent trail that will attract foxes.

Landowners and occupiers may lay baits on their own property, unless that property is within a built-up area or is gazetted a "special rural" zone, in which case special regulations apply.

It is important to check the bait sites, to get an idea of how many baits are being taken. DEC researchers have shown that baiting once a month is sufficient to keep an area reasonably free of foxes, and that baiting less frequently can be beneficial. Uneaten baits should be collected and returned to the APB for safe disposal.

Fumigation of dens can be done with poisonous gas but is only worth doing if young cubs are known to be in residence. The procedure is the same as for the rabbit.

Genetic methods may present a final solution to the fox control problem in Australia and

are being studied jointly by CSIRO, APB, DEC and Curtin University. It involves genetic engineering of a virus that will cause foxes to become sterile. If successful, this programme will lead to fox populations dying out. A similar programme for rabbits is also being investigated.

First, a suitable virus must be found. It must be specific to foxes, spread easily through the population and be suitable for genetic engineering. In the eastern states, fox herpes can be used, but foxes in WA do not have this particular disease so another virus is being sought. Then the virus will be genetically engineered so that it carries samples of fox male and female reproductive proteins. When this virus enters a fox, it will be attacked and destroyed by the animal's immune system, but in so doing, the fox's immune system will learn to recognise its own reproductive proteins as enemies, and so will effectively sterilise itself. It is hoped that this research programme will be completed in 1998.[14]

Exclusion fencing has been designed that will exclude foxes but it is extremely expensive.

Feral Goat

Large numbers of feral goats (*Capra hircus*) occur in the semi-arid shrublands on the outer areas of the wheatbelt, from which they will move into suitable locations - such as hilly country or areas with good shrub cover - where they can escape predators and mustering. They have a wider feeding preference than sheep, taking grass and young regenerating plants when they are available, then browsing a variety of shrubs as the pasture quality declines.

Goats live in small, well dispersed herds when water is abundant but as it gets drier the herds increase in size and congregate near water. The herds, which contain both males and females, are often led by an old female. The size of the home range varies according to the resources available, being small in areas where food, water and shelter are freely available.

Females breed in their first year. Kids may be produced in any month, but the main breeding season is usually during the cooler months. During the first few days, the mother leaves her young hidden during the day while she goes off to feed. Even when her kid starts going with her, the pair remains separated from the herd for a month or so. During this time the kids may fall prey to dogs, foxes, feral cats or even wedge-tailed eagles.

Goats selectively graze out palatable plant species and their activities lead to loss of vegetation diversity and soil erosion. They do extreme damage to remnant vegetation, especially during summer, killing mature plants and totally preventing regeneration. In addition, the paths that they make in hilly country become a focus for erosion. The disturbance, combined with increased nutrients from their droppings, may encourage weed establishment. Goats could become carriers for diseases such as foot and mouth, should they ever become established in Australia. Goats are capable of breeding up extremely rapidly so that a small problem can quickly become a big one.

Goat control

Goats may be controlled by:

- shooting
- trapping
- poisoning
- mustering
- exclusion fencing.

Shooting from the ground is difficult and ineffective as feral goats are fast and live in broken country. Helicopters have been used successfully in pastoral areas but are expensive.

Trapping is probably the most cost-effective way of controlling small numbers of goats.

The recommended procedure is to set a permanent trap around watering points during the dry season.

Poisoning is not recommended until research has established the safest procedure. Some work has been done in New Zealand using 1080 and trials are currently under way near Carnarvon, but there is a high risk of killing non-target species.

Mustering can be done with dogs, provided the country is not too difficult to work, because goats are herd animals. Aerial mustering is also very successful. However, the yards they are run into have to be stronger than those for sheep.

Exclusion fencing such as electric fences have been used to confine domestic goats. Trials in the Goldfields indicate that these may prove useful with feral goats.

Feral Honeybee

The honeybee (*Apis mellifera*) was introduced to Australia in 1826.[15] Escaping domestic bees have established feral colonies throughout suitable habitats, but their year-round need for surface water is a limiting factor in drier areas. They may compete with native animals in two main ways - for food and for shelter. In addition they reduce the pollination success of some native plants.

Honeybees are social animals and if they are feeding in large numbers on a particular patch of flowers they may reduce the food available to nectar-seeking insects such as native bees or jewel beetles, and birds like honeyeaters. They thus have the potential to cause a decline in numbers of native fauna.[16]

Feral honeybees construct hives in hollow trees, in crevices among rockpiles, and under overhangs. Given that these resources are also used by a range of native animals, competition may occur. There are reports of parrots using hollows for nesting, then inspecting and leaving them in breeding seasons after the hollow trees have been taken over by feral honeybees.

The significance of competition for resources has not been widely documented, but will relate to the extent of available resources and the intensity with which they are used.

Honeybees are renowned for their ability to pollinate European plants, with which they have evolved over a long period of time. Australian native plants are adapted for pollination by native fauna, and honeybees cannot always replace them.

Honeybee management

From the viewpoint of both apiarists and conservationists, control of feral honeybees is desirable, due to competition and disease. Currently such control is difficult and rarely practical. However, given that honeybees use resources such as nectar, pollen, and shelter - which are important for native animals - the effects of placing hives in remnants managed for nature conservation should be carefully considered. On the one hand, there may be interference with pollination of particular plants and competition. In other cases, where specific native pollinators have disappeared, honeybees may be able to supply the missing function.

It must be stressed that competitive effects are likely to be greatest when resources are short, for example during poor seasons or at times when there are few plants flowering. Decisions on honeybee management will inevitably reflect management objectives.

Note that honeybees need water, not so much to drink, but to evaporate in their hives to maintain a constant humidity in the brood chamber. While they can fly as far as seven km for nectar, the normal, maximum foraging radius is probably about two km, and apiarists like a constant water supply within about one km of hives.[17] Therefore, if

a remnant is more than two km from an all-year water supply, it may remain free of bees.

Feral Pig

Feral pigs (*Sus scrofa*) are less of a problem in WA than in the eastern states. Nevertheless they are present in forest areas and in the Chapman River system in increasing numbers and cause great devastation to the habitats where they occur. In addition they are subject to a number of diseases, some of which, like Murray Valley encephalitis, are communicable to humans and domestic stock. Both boars and sows (especially when they have piglets) can be aggressive towards other animals, including humans, and a boar's tusks are formidable weapons. They should be eliminated from bush remnants.

Pigs live in loose herds of sows and young, the boars being mainly solitary except at mating time. They forage at night, though in cool weather they may be active during the day as well. They are omnivorous, eating plants (especially roots and tubers), insects and any live prey they can catch. Carrion is regularly consumed, to the extent that if a pig dies it will be eaten by the rest of the herd.

A female breeds when seven months old and can have two litters in a year. She constructs a nest of dense grass in which to have her young, usually five or six piglets. Dingoes will occasionally take a piglet, otherwise pigs have no predators.

Pigs disrupt the natural environment in many ways, most obviously by churning up the ground when they root for bulbs and insects, or constructing wallows in which they lie during the heat of the day. In the jarrah forest they cause considerable damage to the streamside vegetation in this way, making it unsuitable for use by native animals such as quendas and tammar wallabies. Also, being large and aggressive, they will drive out potential competitors, even if they do not actually eat them. They also foul watercourses.

Pig Control

Pigs can be controlled by:

- shooting
- poisoning
- trapping.

Shooting is difficult as pigs live in dense cover. The meat should not be eaten as it is likely to contain parasitic worms which can be transferred to humans. Their meat may also contain hydatid worms which are transferred to humans via dogs.

Poisoning should be done in consultation with the local APB officer, who will do the actual poisoning, using 1080 baits.

It is essential first to accustom the pigs to eating the chosen bait, so food must be put out for them at a suitable bait station. This is called free-feeding. Pigs need to become accustomed to eating a large amount of free feed before being offered poisoned bait, or they may refuse it or eat only enough to make themselves ill, and then remember not to touch bait in future.

Once the pigs are taking the feed freely and in large quantities, an APB officer can administer the poison.

Trapping is possible but it is a costly and time-consuming business and should only be used when poisoning is not possible, for example when domestic stock also have access to an area. Free feeding (see above) is an essential preliminary step and should continue while the trap is built around the bait station. Many different designs of traps are available.

Rabbit

Rabbits (*Oryctolagus cuniculus*) were introduced into Australia from England in 1858 and have colonised most of the southern half of the continent, despite many

thousands of kilometres of barrier fences which were erected to try to stop them. They have caused enormous loss to agriculture and severe devastation to the natural environment. Effective rabbit control is important for the protection of remnant vegetation.

Rabbits are basically social animals, resting during the day and feeding at night. In WA rabbits normally shelter under dense vegetation and only use a warren for breeding. They prefer to eat green, growing vegetation, and will select the choicest morsels, but under stress will eat bark, roots and any plant material available.

Rabbits become sexually mature at three to four months and, depending on resources (they must have actively growing vegetation before they will breed), can have up to six litters a year. The number of young produced annually by a female rabbit varies according to the conditions; 30 have been recorded for the Cape Naturaliste area.[18] The main predators are foxes, cats and wedge-tailed eagles, but the virus myxomatosis still kills a large proportion of the population.

Rabbits are selective grazers but eat many native plants and dramatically degrade those that are to their liking, for example the flowering shoots of orchids. Thus in areas with moderate rabbit grazing pressure, flowering orchids will be found mostly within the shelter of a non-palatable plant, such as a very prickly bush or a reedy clump. When the grazing pressure gets higher, or drought stress occurs, rabbits can totally denude an area, even killing shrubs and small trees by ringbarking. Their presence always severely limits regeneration as they selectively graze seedlings and fresh resprouts.

As they reach high numbers and open up the canopy of the shrub layer, rabbits not only affect the plant community but make it unsuitable for use by some native fauna. For example on the Nullarbor, the chiming wedgebill and the Nullarbor quail-thrush have disappeared from areas where rabbits have opened up the vegetation.[19]

The construction of a warren causes huge soil disturbance, destroying vegetation both by burying and by root destruction. Almost more important, though, is the fact that the soil disturbance creates suitable sites for weed invasion. So also does the rabbits' habit of depositing their dung in specific piles. This selectively increases the nutrient status of the soil which, together with soil disturbance, encourages weed invasion.

Rabbit Control

Rabbits may be controlled by:

- shooting
- poisoning
- fumigation
- warren destruction
- genetic methods (currently being investigated)
- exclusion fencing.

Shooting is not effective on its own, due to the rabbits' renowned capacity for breeding.

Poisoning with trails of oats containing 1080 can be very effective in reducing numbers, especially if done in late summer/early autumn before the breeding season. Pindone, an alternative poison, should not be used in bush areas as native animals are susceptible to it.

Care should be taken to exclude stock from baited areas, and also to place poison trails where native seed-eating birds will not be attracted to them. Failure to observe these precautions may reduce the effectiveness of the control measure on the rabbits and may lead to bird deaths. Galahs and 'twenty-eight' parrots, for example, have some resistance to 1080, but the large quantities which they could ingest if they followed a poison bait trail could be fatal. It is

Figure 8.3 Summary of rabbit control methods[20]

Method	Time of year	Environmental hazard	Health hazard	Cost	Benefit
Fumigation	best after opening rains before breeding	low	care needed	labour intensive	use among bush and rocks
Warren destruction	summer for sand, winter for clay	soil erosion, damage to native vegetation	low	moderate	effective for paddock infestations
Rabbit-proof fencing	any	nil	nil	high	long-term effect, permits regeneration
Conventional 1080	best late summer/early autumn	low	care needed	low	effective, cheap and safe for native fauna
Contract poisoning, 1080 one-shot	late summer/ early autumn	low	care needed	low	safe for native fauna, best for unskilled or busy landowner
Contract poisoning, pindone	best late summer	fatal to native animals	low	moderate	safe for domestic animals
Shooting	any	nil	care needed	moderate	useful for very small populations

especially important not to bait near dams or watercourses as some waterbirds could be at risk.

Weather conditions will affect this technique, as 1080 is highly soluble in water, so rain will quickly destroy the effectiveness of baits.

Fumigation of the rabbits' warrens with a poisonous gas can be effective. This is a useful technique where there are isolated colonies of rabbits or the warren is in an area where ripping is impossible or would do too much damage, such as in a rock pile or among native vegetation. It can also be done as a follow-up to a poison campaign. As with other control methods it is best done following the opening rains and just before the breeding season.

Destruction of warrens is important in a control program so that they cannot be recolonised by a new generation of rabbits. Where it occurs in an open area, the warren can be ripped but this is very destructive if it is done amongst native vegetation. If done with care, single holes can be dug up with a backhoe, after which the soil is replaced and smoothed off to discourage re-occupation of the site.[21]

A technique that has been used with some success by DEC's Ken Atkins is to use an explosive that implodes (i.e. blows downwards into an area of greater density, rather than an explosion, which would leave a crater), such as ANFO. Plastic bags containing 250 gm of ANFO buried 50 cm deep over the warren and then detonated will cause the warren to collapse with little damage to the vegetation except directly over the charges. (Note that a shot firer's licence is required.) This technique works best in sand, which is loosened by the blast and thus rabbits are not able to dig the warren out again.

Finally, do not create ideal sites for new warrens by heaping up piles of soil and debris among existing bush.

Genetic control is being investigated in a program co-ordinated by CSIRO in Canberra, to create a virus by genetic engineering which would cause the rabbit population to become sterile. The principle is the same as that outlined for the fox and the two viruses will be released simultaneously.[22]

Exclusion fencing is probably too expensive for normal consideration. However, rabbits hinder regeneration and so if a good level of control cannot be achieved by other means, exclusion fencing may be considered where regeneration is being encouraged, and especially in areas of direct seeding.

Native Animals

Introduction of agriculture has changed the environment in WA, favouring some native animals and not others. The provision of resources such as abundant food - especially grass and grain - and fresh water has allowed some animals to increase to such an extent that they may cause economic losses to agriculture and may also damage remnant native vegetation.

It may be necessary to control the numbers of these animals to limit their effect on agricultural and natural resources.

Difficulties arise in that some animals may roam widely in response to breeding or seasonal conditions, so that a perceived problem may only occur at one time of the year. Little corellas, for example, may be a considerable problem during the summer when they gather together in large, noisy, sometimes destructive flocks in certain favoured areas - such as Dongara or Dalwallinu. During the breeding season they disperse to many different sites and the individual pairs are far less obvious.

Ideally the carrying capacity, that is, the optimal numbers of a particular species that an area could support without damage, would be assessed. This is difficult to do,

Figure 8.4 Effects of principal problem native animals

ANIMAL	EFFECT ON AGRICULTURE	OTHER EFFECTS
Dingo	may kill domestic stock	predates large animals (for example kangaroo) thus helps to keep numbers in check may control exotic predators, i.e. cat and fox
Kangaroo	may compete with stock for pasture and water may damage crops may damage fences	may affect regeneration of native plants
Emu	may damage crops may damage fences	disperses seeds (for example sandalwood) controls insect numbers
Wedge-tailed Eagle	may take lambs (but rarely does so unless the lamb is already sick)	preys upon rabbits removes carrion
Parrots	some species may damage orchard crops some species may attack stored grain some species may cause damage to seedlings and young trees	some species may cause the death of blackboys some species may ringbark trees around their nesting hollows
Waterbirds	some species foul farm dams some species damage seedlings, young trees, and crops and pastures	

however, as animals are often highly mobile, may be secretive and are not constrained by property boundaries. This is one reason why State-wide bodies are responsible for taking control decisions.

The aim of native pest animal management is to control populations and their rate of increase so as to limit damage and to maintain the population at a biologically sound level. A problem with this approach is that at some times nearly the whole population of a species may be present in a relatively small area. Thus decisions on carrying capacity can be made only in the light of understanding the biology and range of the species concerned.

Legal Aspects

All species of native fauna are protected under the Wildlife Conservation Act unless declared otherwise by the responsible Minister. This means that they may only be taken (killed or captured) under licence issued by DEC. An exception to this is where open seasons are declared for particular species under the Wildlife Conservation Act. Examples of these will be dealt with below.

Several species which are deemed to cause damage to agricultural production may be taken for the purpose of mitigating damage. Some of these animals have also been declared Native Pest Animals (Category A7) by the APB. They are subject to management plans prepared by the APB in consultation with DEC in accordance with the Acts and Regulations of both bodies.

Except for those species where an open season has been declared, a damage licence must be obtained from DEC before control action is taken. Damage licences are issued for specific situations and may have conditions attached. Often disturbance is encouraged as a first option, and only if that does not mitigate the problem will destruction of animals be authorised.

For some native fauna, an open season may be declared in certain shires. Conditions under which an open season operates vary according to the circumstances. For example, in certain shires where fruit growing is a significant economic activity, open seasons have been declared providing for the control of some parrots when they are causing damage, or may reasonably be expected to cause damage, to fruit or flower production.

In some seasons large numbers of ducks may congregate on farm dams, causing fouling of the water. Damage licences can also be issued for the management of these animals.

Dingoes are an exception to these regulations, as they are declared under the Wildlife Conservation Act not to be protected fauna. Property owners may take measures to control them on their own land without reference to DEC. However, if the dingoes which are causing concern are on Crown Land, a landholder should approach the APB who will liaise with DEC concerning control measures that might be taken.

Native Animal Management - Individual Animals

Dingo

Dingoes (*Canis familiaris dingo*) were probably brought into Australia from south-west Asia some 8 000 - 3 000 years ago and have spread through the mainland, though they never reached Tasmania or some of the islands. They probably displaced the Tasmanian tiger from the mainland.[23] Dingoes interbreed freely with other dogs and the term wild dog is often used to refer to dingoes, hybrids and feral dogs.

As a carnivore, dingoes will take whatever prey is easily available - on the Nullarbor, for example, they live mostly on rabbits, while in the Fortescue area they prefer euros and red kangaroos. They will take sheep and occasionally calves, and

their hunting behaviour may lead to harassment and maiming of sheep, and these losses can be significant.

Dingo Control

Dingo control in WA is co-ordinated by the APB. It is based on the premise that dingoes and sheep cannot co-exist, and therefore a policy is pursued of eradicating dingoes within closely settled areas and creating a dingo-free buffer zone between sheep paddocks and dingo populations. Poisoning using 1080 baits is the method usually employed, although steel-jawed leg traps and shooting may be used in particular situations. In all cases where wild dog activity is suspected contact the APB for advice and assistance.

This eradication policy could cause a conflict of interest where the adjoining land use is designated for nature conservation, for example a national park or nature reserve, as there is a body of opinion which believes that dingoes should be allowed to survive in such areas. In areas managed by DEC, an officially approved dingo management programme may be operating. Contact the local DEC office for details. Exclusion fencing could be considered to separate dingoes from sheep. Netting fences have been used very successfully for many years in the eastern states and electric fences have also been used. However, such fences are expensive to construct and to maintain.

Kangaroos

In agricultural parts of WA three species of kangaroo are capable of causing a problem for land managers.

Red kangaroo (*Macropus rufus*) - found in the outer edges of the wheatbelt, adjacent to pastoral areas.

Euro (*Macropus robustus*) - populations occur, often in hilly country, in the northern, central and eastern wheatbelt.

Western grey kangaroo (*Macropus fuliginosus*) - occurs throughout the agricultural area.

Notes here refer to these kangaroos unless otherwise indicated.

DEC has produced management programmes for these three species.[24] They are based on the principle that viable populations of kangaroos should exist in areas set aside for nature conservation and in other lands including those used for primary production. If agricultural production is adversely affected by kangaroos, the management programme stipulates how their numbers may be reduced. Thus the programmes are designed:

- to maintain populations of kangaroos over their natural range in WA
- to contain the deleterious effects of kangaroos on other land management practices
- to manage kangaroo species where possible, as a renewable natural resource providing the conservation of the species is not compromised.

Kangaroos graze crops and compete with stock for feed and water. In natural bush, vegetation and kangaroos evolved together and the bush has developed strategies to cope with kangaroo grazing. However, where there is a high density of kangaroos in remnant vegetation their grazing may inhibit regeneration. They definitely need to be excluded from direct seeding areas. In addition, they can damage fences.

Crop damage varies depending on the species of kangaroo, the season, and the type of crop. Graham Arnold of CSIRO studied grey kangaroos in the Baker's Hill area, where crop and pasture paddocks were interspersed with remnant wandoo woodland.[25] He sowed experimental patches of crop in pasture paddocks and found that kangaroos caused significant reductions in grain yields. However, because of the small

Left: *Many eucalypts regenerate well on the ashbeds created after a fire. Here wandoo and powderbark seedlings have germinated. York.* *(Penny Hussey)*

Below: *Fire as a management tool in isolated bush areas should be treated with very great caution, as it can also destroy the community it was designed to regenerate. The experimental fire on this roadside failed to regenerate the banksia shrubland because of several unforeseen factors, including a non-wetting wind-deposited soil profile, unchecked weed competition, rootstocks buried too deep for regeneration and a very dry following summer. Moral: be extremely cautious.* *(Main Roads)*

Above: *These swamp mallets were accidentally burnt and excellent regeneration has occurred. Ongerup.*

Below: *In 1966 a large heap of tree debris was burnt. This stand of young salmon gums and York gums has grown on the site. Note mature salmon gum in the foreground and York gum behind, which would act as seed trees. Northam.* *(Penny Hussey)*

size of the trial plots, the effect on crop yield was greater than would be experienced in a normal paddock situation. Worst affected were lupins - perhaps because they are more sensitive to grazing - then oats, barley and wheat. Crop damage was most severe adjacent to woodland, and no grazing was observed more than 400 m from cover.

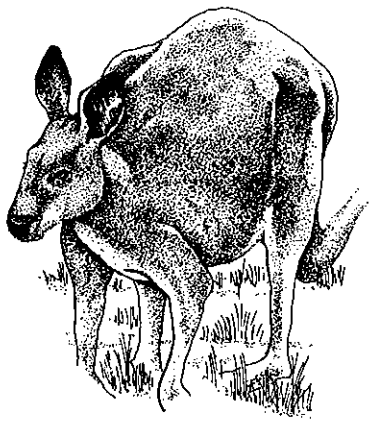
Competition with stock for pasture does occur. It has been estimated that, compared to a sheep, a kangaroo eats seven-tenths as much food and drinks half as much water.[26] However, except during a drought, they may not be in direct competition, as they have different dietary preferences. In bush areas, for example, grey kangaroos will seek out and graze certain native grasses, ignoring any exotic grasses that might be present, and also eat the growing tips of some particular shrubs. Sheep may eat the exotic grasses first. Like other grazers, kangaroos exhibit a preference for tender young plants and so they will preferentially graze regenerating vegetation, especially non-prickly seedlings, although this may only be a problem where numbers are unnaturally high.[27] Heavy grazing pressure from kangaroos can prevent natural regeneration almost as effectively as heavy grazing pressure from stock, although it does less damage to the soil structure.

Fences in good condition will usually keep grey kangaroos out unless their numbers are very high. Damage to fences is most noticeable where the fences are in poor condition. Grey kangaroos tend to gully underneath fences and are capable of digging out new gullies if necessary. Special gates can be constructed to allow them through if desired. Euros tend to make holes, especially in netting fences. Electric fencing has proved effective in barring kangaroo movements.

Grey kangaroos at Yalambie, Bakers Hill[28]

In this area, where interconnected patches of wandoo woodland totalling 305 ha are surrounded by farmland, CSIRO's Graham Arnold studied a sub-population of grey kangaroos for ten years. There was almost no immigration or emigration and the population numbers were relatively stable, regulated, it would seem, by a high mortality of the young. After culling in 1983 there was only a slow increase back to the previous density.

Localised culling is effective in controlling numbers.



Carrying Capacity

In agricultural areas with about ten per cent of bush left among farmland, the numbers of grey kangaroos are essentially stable. However, build-up of numbers can occur where there are a few small remnants and the kangaroos depend almost entirely on farmland for food. In pastoral areas, the numbers of all kangaroos fluctuate widely in response to seasonal conditions.

It follows that a management programme can be worked out to enable a viable population of kangaroos to exist within a farming area. The difficulty lies in determining the appropriate number of animals. To regulate the commercial industry, a State-wide assessment of overall kangaroo population trends is carried out by checking the monthly returns of commercial shooters, ground surveys, triennial aerial surveys and patrols by DEC and APB officers.

Graham Arnold's work on grey kangaroos at Baker's Hill and Kellerberrin provides some facts to work with.

Firstly, grey kangaroos have fixed home ranges and seldom move to new areas. It appears that home ranges are determined by following the mother's behaviour, as in sheep. At Baker's Hill, one female was caught 12 times over nine years, each time in exactly the same place.[29] At Kellerberrin, animals tended to remain close to larger patches but to move between smaller ones, mostly along fencelines or road verges, and sometimes across open paddocks. They commonly travel two km between remnants but will travel up to five km. Because of this essentially sedentary behaviour they form sub-populations with not much movement between them (see diagram on page 133). Thus occasional localised culling may be sufficient to control pest problems by grey kangaroos (and possibly also euros).[30]

In a culling operation undertaken within a conservation reserve in the south-west of WA, it was decided to cull one quarter of the animals visible on the farmland adjacent to the reserve boundary (i.e. 10-15 per cent of the estimated total population on the reserve) and to take an equal number of males and females, but to specifically avoid females with visible joeys in the pouch. A professional shooter was engaged and the exact cull ratio achieved, apparently mitigating the problem to the satisfaction of the adjoining landholders.[31] The more usual situation would be to cull across all age and sex classes as the animals are encountered, and this would probably be just as effective.

If the decision to cull grey kangaroos on farmland is made, those guidelines could be followed in the first instance, and the situation observed for six months before further action (if any) is taken.

Red kangaroos are a somewhat different case, as they can be more mobile, and congregate on green feed, which, at the edge of the wheatbelt, means farmland. In these situations culling may not permanently reduce the numbers. Control as required and install exclusion fencing if it is feasible. Outside the agricultural area, red kangaroos are managed as part of the commercial kangaroo industry. Management of this industry is not considered here.

How Many Kangaroos in an Area?

Unfortunately, there is no hard and fast rule for how many kangaroos a piece of land can support. Where small (about 20 ha) remnants are surrounded by crops, it is possible to make an estimate.

To determine the population numbers that are sustainable in a mosaic of bush remnants and farmland, it is necessary to consider four points:[32]

What is the size of the sub-population?
This can be estimated by observation at dusk, with numbers of animals seen in the paddock being probably 33 per cent of the population in a good season, 50 per cent in a poor season.

What is the condition of the remnant vegetation available as habitat?
Shrub cover is necessary for animals to use a bush remnant. They will not use a site with trees but no understorey unless it is over four ha in size. Nor will they use bush adjacent to houses and yards. The better quality the bush, the higher the kangaroo population is likely to be.

What is the probability of recolonisation of remnant patches after a catastrophe?
Good quality bush corridors between remnants will give a better chance of recolonisation, remembering that grey kangaroos regularly move two km between remnants, but do not travel further than five km.

What is the chance of inbreeding affecting the population?
If the population is isolated, and culling reduces the numbers substantially, inbreeding may occur and cause problems for long-term survival. Sub-populations connected by bush corridors along which dispersing individuals could move, are likely to have the best chance of retaining genetic health.

After looking at this, and observing damage to both crop and bushland, a landowner would be able to make the best possible decision on the management of kangaroo numbers in each individual situation.

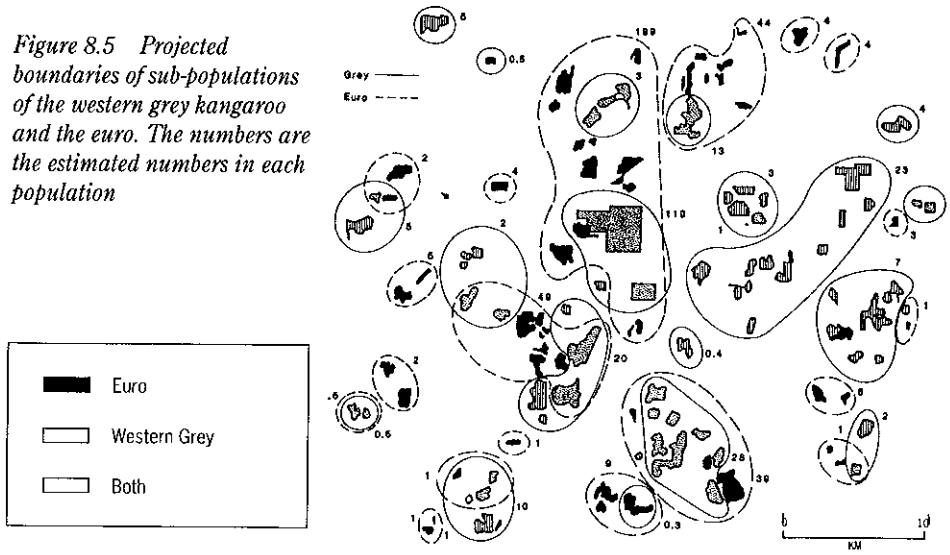


Figure 8.5 Projected boundaries of sub-populations of the western grey kangaroo and the euro. The numbers are the estimated numbers in each population

Exclusion fencing is reported by several landowners to keep kangaroos out of crops - even lupins. This in itself is likely to limit population numbers to that which can be supported by bush alone.

Shooting

Landholders may shoot grey kangaroos:

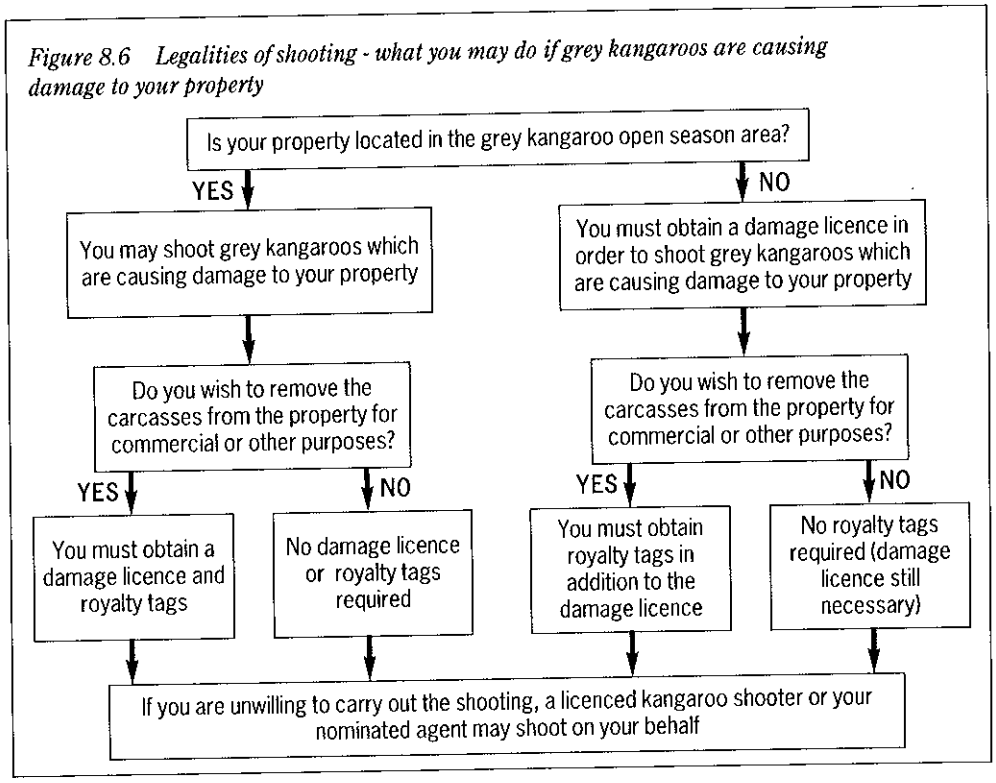
- on their own land without a licence if an open season has been declared in that area, provided that no commercial use is made of the animals and carcasses and skins do not leave the property
- on their own land under the provision of a damage licence if the property is not in an open season area, or if the carcasses or skins are to be used commercially or moved from the property. If carcasses are to be sold, they must be tagged. These royalty tags may be purchased from DEC.

A professional shooter's licence may be issued by DEC which empowers the shooter to kill kangaroos for commercial purposes in a specified area in a specified year. Carcasses are identified by a royalty tag and shooters are required to submit monthly returns on their operations to DEC. Total numbers of each of the three commercially used species which may be killed in the State in any year are subject to a quota. The quotas are determined by considering current population trends, seasonal conditions, the numbers taken in previous years, current land use, and the proportion of habitat not subject to culling.

Trapping is illegal and kangaroos can be killed only by using a licenced firearm.

Poisoning is illegal. Kangaroos can be killed only by using a licensed firearm.

Figure 8.6 Legalities of shooting - what you may do if grey kangaroos are causing damage to your property



Emu

The emu (*Dromaius novaehollondiae*) is a large flightless bird which used to range over all of WA. It is nomadic and usually moves in small family groups, but sometimes congregates in large flocks as a response to seasonal conditions.

Emus can live in a variety of habitats from woodlands and heath to open spinifex country. They are omnivorous, taking what food is available at the time: grass, nectar-laden flowers, seeds and fruits (including grain), or large insects. They are especially partial to grasshoppers. This varied diet means both that they must move to where the food is and that they will survive very well in agricultural areas as long as there is some bush around for shelter.

Emus are large birds and they can cause reduction in yield from crops, not so much from what they consume, but rather because they trample the crop while moving through it. They do not compete with stock in pasture paddocks as their dietary preferences are different. Indeed, they may be beneficial in such situations, as they will seek out and eat beetles, large caterpillars and especially grasshoppers.

Emus can cause damage to fences, as they tend to barge straight through them, especially when being pursued.

Emu Control

Emus are protected fauna under the Wildlife Conservation Act, and management aims to conserve emus whilst at the same time protecting farmers from unacceptable damage.

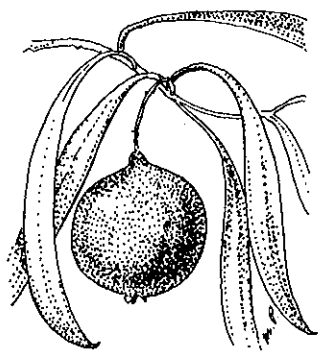
The APB maintains the State Barrier Fence between the pastoral and agricultural areas which keeps out major migratory flocks. In the agricultural areas, shooting and poisoning can be used for control.

If crop damage is observed, damage

Emus and sandalwood

Sandalwood and quandong (*Santalum acuminatum*) trees produce seeds enclosed in a hard shell within a fleshy outer covering. Emus eat these but their digestive juices, which cope well with the outer flesh, merely soften the hard shell without getting at the seed inside. While in the digestive system, they function as grindstones. Eventually the seed is voided in their droppings. There, in its own pile of manure, the seed germinates. This is how sandalwood, quandongs and zamias (which have a similar type of fruit, though much larger) are dispersed naturally away from the parent tree.

If there are no emus left in an area, people can take over their role by collecting fallen nuts from beneath a tree, cracking the shells (but not the seeds) using a file or vice, and burying them in an area where you would like a new population to become established. The seedlings are very palatable, and grazing by stock, rabbits or kangaroos will eliminate them.



Quandong fruit

licences to control emus can be obtained from DEC, after which landowners may reduce the numbers on their land by shooting. No commercial use of the skins or carcasses is allowed.

Where large numbers (more than 30) are present and feeding in one area, poisoning during the winter months with strychnine-baited wheat could be considered. In this situation, a Wildlife Officer from DEC must inspect the site and give approval for the poisoning campaign, prior to the issue of a damage licence. Because of the possible effects on other wildlife, the licence conditions include clauses which insist that the campaign be carried out by officers of the APB. This method of control is not recommended.

It is interesting that in the eastern states, emus are not seen as a problem for agriculture; in fact most farmers welcome the birds as an additional attraction in the landscape.

Wedge-tailed Eagle

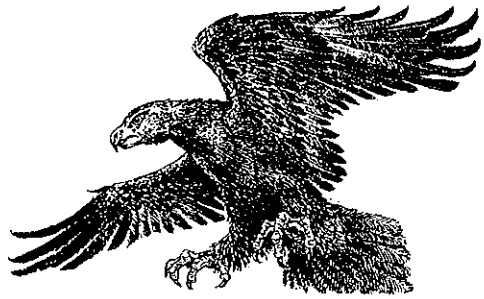
The wedge-tailed eagle (*Aquila audax*) is Australia's largest bird of prey, with a wingspan of about 2.5 metres. It nests in high places and hunts in open areas. Adult pairs are usually sedentary and will defend their territory against other eagles. In a good season two chicks might be reared, but it is usually only one. In a poor year the animals may not breed at all. Immature animals are nomadic, moving to seek new areas.

Wedge-tailed eagles have an extremely varied diet, a large portion of which is carrion. They often hunt along road verges looking for animals killed by vehicles, but they do take live prey. In many places they subsist almost entirely on rabbits, and they will take reptiles, birds and mammals as large as a medium-sized kangaroo. Lambs taken have been shown by several recent studies to be sickly or already dead, and the extensive damage attributed to eagles in the past has been exaggerated (including a report that they killed a horse!).[33]

There is no economic reason to control wedge-tailed eagles in any but very exceptional circumstances.

Wedge-tailed eagles are protected under the Wildlife Conservation Act. If it can be shown that they are causing damage to stock, a landowner may shoot the offending birds after receipt of a damage licence from DEC.

Wedge-tailed eagle



Parrots

A number of fruit and grain eating parrots and cockatoos cause problems in agricultural areas by damaging crops and, in some instances, remnant vegetation.

Most of these birds have increased in numbers and expanded their range since agricultural clearing, as the mixture of farmland and bush, together with a constant supply of fresh water, has provided ideal conditions for them. The greatly increased numbers are putting pressure on the remnant vegetation in which they live and may be causing the displacement of less common species, especially hollow-nesting mammals and other birds.

Control of parrots in orchards: various scarecrow types of devices have been used to deter parrots from entering orchards, with varied success. The only sure way of preventing parrot damage is to net the tree or the entire orchard which may be a commercially viable option in some situations.

Declared birds, category A7, that are considered native pest animals may be subject to an open season in some local authority areas. In open season areas these birds may be shot, without a licence, by land or lease holders (or their approved nominated agent) on their property when the birds are causing, or could be reasonably expected to cause, damage to property or production. In shires outside open season areas, if damage to agriculture can be shown, they may be controlled by shooting after a damage licence has been obtained from DEC.

The birds which may be seen as causing a problem are discussed below.

Little Corella

Little corellas (*Cacatua pastinator*) once were not found south of the Murchison. They are expanding into the wheatbelt, which is excellent habitat for them, as it provides hollow trees for nesting, permanent fresh water and plenty of food. They live in large, noisy flocks which gather together in preferred trees to roost at night and at mid-day. They feed in open areas, mainly on the ground, eating grain and other seeds including doublegees, insect larvae, bulbs and roots. During the hottest part of the day they shelter in trees, often stripping leaves and nibbling bark. In the breeding season, pairs leave the flock to live separately.

Little corellas will take sown grain and compete with stock for grain laid as feed trails. They will pull up seedlings and defoliate trees.

In addition, for anyone who happens to live near a roosting tree, they are very noisy.

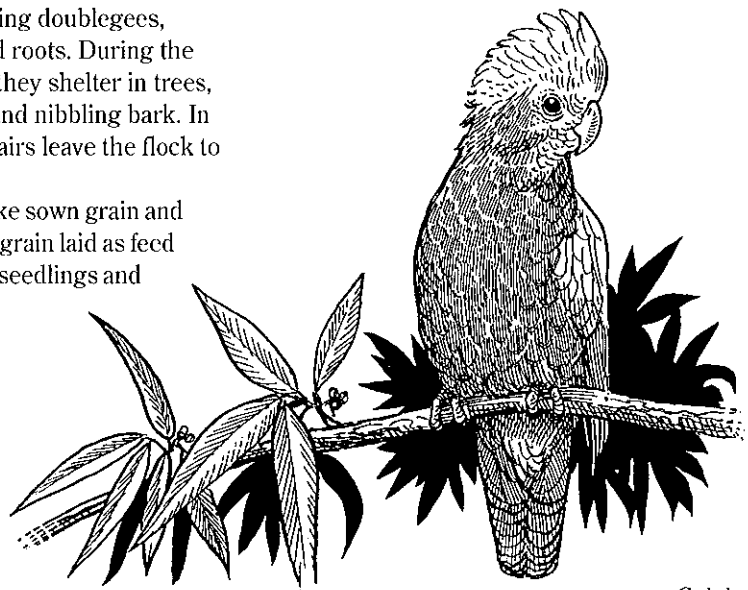
A declared bird, category A7, and native pest animal, the little corella is subject to an open season in some local authority areas.

Galah

The galah (*Cacatua roseicapilla*) was originally a bird of watercourses in the arid zone, but it has expanded its range almost throughout the wheatbelt (it has not yet reached Esperance, but in 1991 a pair was reported to be nesting at Gibson). It forages principally on the ground and will eat some foliage, seeds, grain, bulbs (including Guildford grass and cape tulip corms), and many sorts of insects and their larvae.

Galahs take sown and sprouting grain from paddocks, uproot seedlings, ringbark branches and contribute to tree defoliation. They also occupy nesting hollows formerly used by other species, such as Carnaby's cockatoo.

A declared bird, category A7, and native pest animal, the galah is subject to an open season in some local authority areas.



Galah

Red-capped Parrot

The red-capped (or king) parrot (*Purpureicephalus spurius)* is a bird of the forested south-west. It eats eucalypt seeds, especially marri, and also many other seeds, including grevilleas, thistles and capeweed. During the breeding season it will take insect larvae. It relishes the seeds from apples and pears but will tear into other soft fruits for the juice. Red-capped parrots can damage flower crops such as proteas.

A declared bird, category A7, and native pest animal, the red-capped parrot is subject to an open season in some local authority areas.

Red-capped parrot

'Twenty-eight' Parrot

'Twenty-eight' parrots, also known as Port Lincoln ringnecks (*Barnardius zonarius*), have exploded in numbers over recent years, responding to the agricultural pattern of open areas interspersed with patches of timber and plentiful fresh water. They forage on the ground or in trees and shrubs eating a variety of seeds, fruits, and insects. They cause problems in orchards by eating all soft fruit, especially as they try everything to see if it is ripe, and thus ruin more than they eat.

They cause damage to grass trees (*Xanthorrhoea* spp.) by their habit of ripping out the leaves to get at the soft portion at the centre of the stem. This damages or kills the growing point, and may destroy the plant. It is not known whether the animals learn from each other to do this, but the practice is increasing.[31] There appears to be no way of stopping them, short of netting the plants to exclude parrot access.

As discussed in chapter 7, 'twenty-eights' may compete with rarer birds for nest hollows, thus threatening the reproduction of more desirable species.

A declared bird, category A7, and native pest animal, the 'twenty-eight' parrot is subject to an open season in some local authority areas.

Western Rosella

Western rosellas (*Platycercus icterotis*) are found in the forested south-west and wheatbelt woodlands. Like other parrots, they eat seeds, fruits and insect larvae, and can become a pest in orchards. However, the long-term survival of this species in the wheatbelt is threatened.

A declared bird, category A7, and native pest animal, the western rosella is subject to an open season in some local authority areas.

Smokers

Smokers, also known as regent parrots (*Polytelis anthopeplus*), occur in forests and woodlands except in the extreme south-west, although they are moving into this region. In the past, the population has suffered a decline, from which it is now recovering. They feed on seeds, fruits and buds, both in tree and shrub canopies and on the ground. They may destroy orchard fruit, but the damage they may do is nowhere near as significant as that caused by 'twenty-eights' and red-capped parrots.

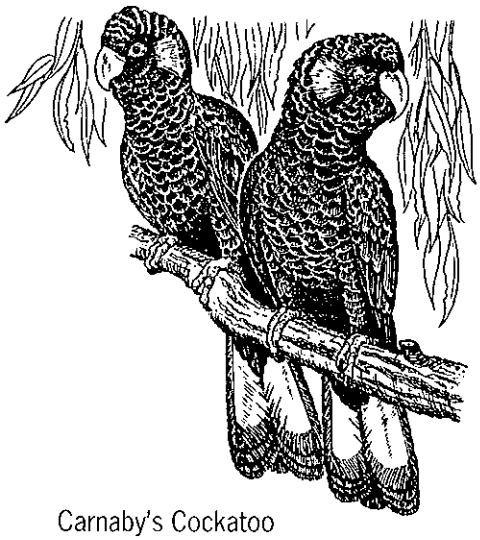
If landholders consider that smokers are causing problems, then they should contact the nearest DEC office and seek a damage permit.

Baudin's Cockatoo

Baudin's cockatoo (*Calyptorhynchus baudini*) lives principally in forested areas of the south-west where it is heavily reliant on marri trees. Their seeds are its main food source. It eats the flowers for nectar and digs out borers from the branches and trunk of the trees, creating a wound like a vertical chain-saw cut. They will take borers from other trees, and can damage timber plantations - especially pine - in this way. In orchards, apple and pear crops can be damaged. Not only do the birds take the fruit, but they damage branches as they search for grubs.

If Baudin's cockatoos are causing damage to cultivated fruits, landowners may apply to DEC for a damage licence, after receipt of which they may shoot the birds. It is not legal to take them by any other method or in any areas other than orchards.

Baudin's cockatoo is a declared bird, category A7, considered a native pest animal.



Carnaby's Cockatoo

Carnaby's cockatoo (*Calyptorhynchus funereus latirostris*) as a rule lives in drier woodland, though it does overlap with Baudin's cockatoo. It is a very similar bird and it too feeds on seeds, nectar and insects. Preferred plants include banksias, dryandras, grevilleas and hakeas, but it has learnt to eat pine seeds and can cause considerable damage to plantations.

This cockatoo is decreasing in numbers due to loss of its breeding habitat in the wheatbelt and there should be no need to cull any flocks.

Carnaby's cockatoo is fully protected and may not be taken.

Red-tailed Black Cockatoo

Red-tailed black cockatoos (*Calyptorhynchus magnificus*) have increased since clearing, and moved into the northern wheatbelt where large flocks are often seen in paddocks. They are not eating grain but the seeds of doublegees, or of corkscrews, both troublesome weeds. There is no reason to consider that their numbers should be reduced.

Red-tailed black cockatoos are fully protected and may not be taken.

Waterbirds

Problems are sometimes caused in agricultural areas when waterbirds foul farm dams or damage planted tree seedlings. The two most important species are probably mountain duck (*Tadorna tadornoides*) and wood duck (*Chenonetta jubata*). Both are large birds that nest in tree hollows and graze in paddocks. Their habit of camping, often in quite large flocks, in favoured spots close to dams, may lead to excessive nutrient pollution of the water. In addition, they graze and browse extensively, and may uproot planted seedlings.

If tree-planting is undertaken around dams where mountain ducks are known to occur, the seedlings can be protected by a netting guard or something like a grow-tube until they are established.

If damage to agriculture or dams can be shown, they may be controlled by shooting after a damage licence has been obtained from DEC.

9 Fire Management

- The fire regime
- Fire and plants
- Fire and weeds
- Fire and animals
- Fire and the spread of disease
- Fire, the soil and nutrient cycling
- The use of fire
- Fire hazard reduction
- Fire for ecological management
- Special management considerations
- Regeneration techniques
- Legal aspects

Bull banksia

With flammable vegetation, dry summers and sources of ignition it is not surprising that fires are an important component of ecosystems in south-western Australia. Native plants and animals have evolved various strategies which enable them to persist in this environment.

Once humans moved to Australia, natural fires started by lightning were supplemented by fires lit by Aboriginal people; thus in some areas the nature of the fires and the frequency with which they occurred probably changed. European settlers changed the fire regime once again.

Uncontrolled fire can endanger human life and does a great deal of damage to property and remnant vegetation. On the other hand, the correct use of fire can stimulate regeneration and regrowth in native bush, thus creating habitats for fauna. Managers must look carefully at all of these aspects when using fire for the management of remnant vegetation among agricultural land.

Fire is a powerful management tool whose impact is especially significant for small or isolated plant communities. It is important to understand how fire may best be used to manage these areas.

The Fire Regime

The effect of fire on natural communities depends on many factors of which the following are particularly important:

- fire frequency
- the time of year
- fire intensity
- the patchiness of the fire
- events, such as rainfall, before and after the fire.

Fire Frequency

For many plants to persist after a fire, they must be able to reach maturity and set seed before they are burnt again. Since plants vary in the length of time they take to do this, it follows that the frequency of fires will have a distinct effect on the composition of vegetation communities.

To preserve the conservation values of bush remnants, it is important that fires do not occur more frequently than the time needed for all the plants to reach adequate reproductive capacity. In addition, adequate fauna habitat should be maintained. Plant growth and the time taken to flower and set seed is generally much slower in drier areas, therefore the interval between fires in these zones should be longer than in the forested areas of the south-west.[1]

Fire Season

The time of year in which the fire occurs will make a considerable difference to its impact. In effect, there are three possible seasons:

- midsummer/autumn
- winter
- spring/early summer.

Midsummer/Autumn

Effect of fire:

- it is usually hot and intense; the fire front is tall and fast-moving. Fires do not go out overnight
- it consumes most above-ground material
- it is very likely to burn down mature trees

Fire frequency and grass trees[2]

When grass trees (*Xanthorrhoea preissii*) are burnt, a fire scar is left on the trunk. By studying these, and having an idea of grass tree growth rate, it is possible to work out how often these long-lived plants have been burnt. Byron Lamont of Curtin University looked at grass trees in the jarrah forest near Perth and concluded that, in the 150 years prior to European settlement, the plants had been burnt one to three times, that is, an average of once every 50 years. In the 150 years since European settlement, fires have occurred 12-22 times, that is, once every 10 years.

This study indicates that fire frequency in the area of jarrah forest studied has increased greatly in recent times. However, it should be noted that some workers interpret these data differently, because not all fires are intense enough to cause scar formation.

- it will break dormancy for some buried seeds, for example wattles, as dry soil conditions allow greater heat penetration and intense heat pulse from fire (so there is likely to be generally a higher seedling germination and survival rate)
- it may cause high mortality to native fauna.

Prior to European settlement, it is very likely that most extensive fires in the south-west occurred during this time of year. The vegetation is very dry and lightning would have been an ignition source. In addition, the Aborigines used fire as a hunting technique during this season.[3] In the 100 years following European colonisation all notable bushfires recorded as occurring in the settled south-west of WA, whether started by lightning, Aboriginal hunting or Europeans, occurred between November and April.[4]

One good point about burning at this time is that the fire would soon be followed by rain, encouraging good regeneration. Alternatively, very heavy storms could cause run-off and loss of seeds, soil and the nutrients released by the fire, as there will be no plant cover for protection. If burning is undertaken early, then resprouting plants will be large enough by the first winter rains to out-compete species which regenerate only by seed (known as obligate seeders). This is an advantage where weeds are a problem, but may be a disadvantage where managers would prefer to favour a native obligate seeder.

Conclusion: Autumn burning is recommended for most regeneration burns, especially where regrowth of wattle and pea thickets is important. If burning for these purposes, check the soil under the plants for seed, as sometimes birds and ants remove so much that regeneration is poor.[5]

Winter

Effect of fire:

- it has low intensity, the fire front is low and slow-moving, and fires usually go out in the evening
- it is patchy, with areas left unburnt
- it disrupts flowering and seed set for some plants
- it does not crack dormancy of buried seeds
- it encourages growth of grass weeds
- it disrupts the breeding cycle of some fauna
- it is survived by most adult fauna.

A fire at this time of year is unlikely to occur naturally in the south-west of WA. However, there is some evidence of fires at this time at Geographe Bay.[6]

Winter fires will be less intense (a cool burn) and patchy, leaving some organic matter unconsumed - important for litter-feeding animals. They may disrupt the life cycle of both flora and fauna. Some plants will not flower, seed will not be set and many animals' breeding cycles will be interrupted. Winter burns are detrimental to plants which have not evolved adaptations to survive physical fire damage, such as everlastings and most orchids. These plants survive the normal fire season as seeds or tubers insulated in the soil, but they can survive winter fires in unburnt patches.

In drier areas, regeneration burns should be undertaken in autumn. This is shown by the results of two fires at Chiddarcooping Nature Reserve in the north-eastern wheatbelt.

After not having burnt for about 40 years, lightning started a wildfire in Chiddarcooping Nature Reserve in November 1987. This reserve is woodland, mallee and heathland around a series of granite ridges in the 300 mm rainfall belt at

the edge of the wheatbelt. Firecrews cleared a break through the reserve to halt the fire. When it was safe to do so, the bulldozed heaps and some surrounding bush were burnt with a cool, controlled burn in winter 1988.

Rainfall during 1988 and 1989 was very good and regeneration in the area burnt during the wildfire, and on the firebreak disturbed at that time, has been excellent. Very poor regeneration has occurred in the winter-burnt area, either heaps or bush, with large areas of bare ground remaining.[7]

Conclusion: Winter burning is not recommended for regeneration burns in remnant vegetation. However, it may be useful in certain situations, such as to decrease flash fuels around the edge of a remnant or to encourage the growth of one particular plant.

Spring/Early Summer

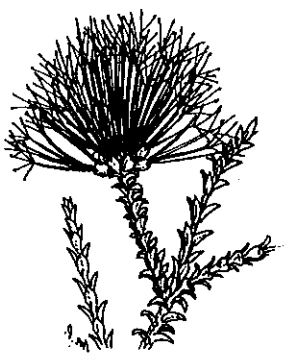
Effect of fire:

- it is of low/moderate intensity, some, but not all, tree crowns will be scorched
- it does not consume all organic matter, some patches may be left unburnt
- it will destroy that year's seed crop for many plants
- it stimulates surface seed germination
- it does not crack dormancy of buried seed
- it may kill many young animals, for example nesting birds, though the adults may escape and there will be colonisation of burnt areas from unburnt patches
- it will encourage the growth of already established perennial grass weeds

Spring fires and seedling regeneration on the northern sandplains[8]

As part of a larger study into the effects of fire on the northern sandplains, research workers from the University of Western Australia studied the effect of the timing of fires on the population of two widespread plants that regenerate only from seed: needles and corks (*Hakea obliqua*) and sandplain bottlebrush (*Beaufortia elegans*).

They found that seedling regeneration is most effective following autumn burns, least effective following spring burns. This was due to two factors:



- the seeds lie on the ground longer, so a higher percentage will be eaten after a spring burn,
- the resprouters regenerate over summer, and consequently have a competitive advantage over any seedlings that establish with the first rains.

Winter and spring burns are clearly unfavourable for the maintenance of these seeders. Thus, if the aim is to maintain all the species present in this vegetation type, autumn burns are the most ecologically suitable.

- it helps resprouting plants grow well over summer and out-compete seeders
- it may weaken seedlings so they do not survive through until the autumn break of the season.

Spring is often favoured for fire hazard reduction burns, as the fires burn well but not as intensely as in summer, and are more predictable than at other times of the year. They are therefore less likely to get out of control. Consequently, burning at this time of the year, in wetter parts of the State, may be easier, safer and less expensive.

These more moderate-intensity burns favour those plants which do not need intense heat to open their seed pods or crack their seed coats - especially grasses and introduced weeds. If thickets of peas and wattles are an important part of the community, these are unlikely to regenerate well. Spring fires occur at the time when most plants are flowering or the seeds maturing, so for these species a whole year's seed crop is lost. Many animals are rearing young which could be killed while still in their nests or dens. However, the more patchy fire leads to a better survival of fauna and a quicker recolonisation of burnt areas than do hotter summer/autumn fires.

Conclusion: Research on the issue of spring fires continues. There are not sufficient data to generalise on whether these burns are best in any particular situation. Spring fires may be desirable in some situations, especially if a remnant has not been burnt for an extremely long period and it is considered that an autumn burn would be too difficult to contain.

In all cases, the burning technique used will be constrained by what can be done safely. Officers of the local Bush Fire Brigade should be consulted concerning restrictions and technical matters before undertaking burning.

Fire Intensity

The intensity at which a fire burns will depend, amongst other things, on the time of year, the air temperature and humidity, the amount and moisture content of the fuel and the soil, and the wind strength. (Note - fires at night are usually less intense than during the day.) Fires of different intensities favour the regeneration of different plants, and low-intensity fires tend to be patchy, leaving areas of vegetation unburnt.

The timing of a fire - and thus its intensity - will affect the plant community that subsequently develops on a site.

But note, response to fires is very unpredictable, especially east of the Darling Range.

Main Roads demonstrated the unpredictability of fire as a regeneration tool in banksia woodlands north of Perth.[9]

A fire intended to investigate weed spread and to regenerate 22-25 year old banksia stands was delayed until after the onset of the rains. Instead of the intense autumn burn they had intended, it was a moderate-intensity fire, hot at ground level where there was grass weed infestation, but only scorching the banksia canopy. The result was a dense germination of *Acacia blakelyi*, which now dominates the site though it had been uncommon before, but only poor regrowth, either by seed or by resprouting, of the banksias.

This points to the importance of only manipulating small areas at any one time, lest something unexpected occurs.

Note also that a dense layer of weed grasses greatly increases the fire intensity at ground level - no matter what the season of burning.

Patchiness

Even in an intense summer wildfire, there are usually some patches of bush which are left unburnt, or only part-burnt. Low-intensity fires leave more and larger unburnt

patches, and the scorch height into tree canopies is much less.

These patches can provide an important refuge for animals during the fire, and may provide essential shelter and food afterwards. They also provide a source of plant seed for re-invasion of burnt areas.

The patchiness of a burn will affect the speed and degree of re-colonisation of burnt areas. This is often an important consideration in the case of isolated remnants of vegetation which would be difficult for many animals to re-colonise.

Unpredictable Events

The impact of unpredictable events is enormous. Thus it is important not to burn all of a remnant in one fire if it is isolated from other bushland. It is also valuable to keep records of events and their impact - we have little information on such things.

Heavy rain after a fire, before the plant cover has grown, can cause severe erosion. The ash and its mineral nutrients, together with seeds that may have fallen upon it, can be removed from the site, severely impeding regeneration and affecting waterbodies. Impermeable soils and steep slopes will show the greatest effects.

Drought in the year following a fire obviously will have a detrimental effect on regeneration, but even a drought before a fire occurs may result in a high level of death among resprouting plants.

Unpredictable events such as insect plagues can have a profound effect. For example, a regeneration burn in Tutanning Nature Reserve during March 1990 produced excellent germination during the following winter. However, that summer there was a locust plague, and the locusts seem to have destroyed all the young rock sheoaks that had grown after the fire. Since sheoak thickets are a major habitat of the

Bull banksia or prickly moses?

In the jarrah forest, adult plants of bull banksia (*Banksia grandis*) normally survive a mild fire and shed their seeds, which germinate well in the ashbeds. An intense fire can kill the plants,[10] reducing the plant density at a site. Prickly moses (*Acacia pulchella*) reacts in the opposite way. It has a very tough seed coat which needs to be cracked before the plant will germinate. During a fire - of any intensity - all wattle seed on the surface is killed. However, ants harvest the wattle seed and carry it underground. The heat from an intense fire cracks these wattle seed coats buried down to 10 mm deep and the seedlings germinate as soon as there is rain. A cool burn does not produce enough heat to do this except in a very few places.

So, just looking at these two plants alone, the type of fire in the jarrah forest will influence what plants dominate the understorey in subsequent years.

red-tailed phascogale, this could have implications for long-term fauna habitat in the burnt area.[11]

Fire and Plants

When an area is burnt, some plants are killed, others receive a setback, yet others are stimulated into germination and growth.

Fire may affect plants directly and indirectly by:

- consuming or severely damaging their aerial parts
- causing stress, which may make the plant more open to infection
- inducing increased seed release
- stimulating subsequent flowering
- inducing germination
- altering the species composition of an area
- releasing mineral nutrients for immediate uptake
- removing herbivores.

The most immediate effect is the impact on the plant itself. If plants are not able to cope with this, they will be eliminated from the area and replaced by others. However, this rarely happens in response to a single fire.

Most WA plant communities have been shaped by fire. It is the most usual mechanism for restarting succession (see chapter 5).

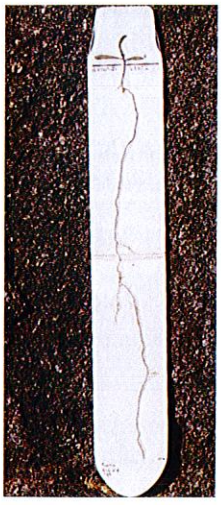
Native plants possess a number of strategies which enable them to survive a fire, either resprouting from underground and aerial parts, or growing from seeds. For example, banksias regenerate well after fire. They open their fruits and release seeds which then germinate and grow in the ashbed. It is often said that these plants need

Regeneration of matchstick banksia[12]

Matchstick banksia (*Banksia cuneata*) grows in a few sites in Quairading, Brookton and Pingelly Shires. It is killed by fire and regrows from seedlings. However, a small number of fruits - three per cent in Quairading - opened in the absence of fire and, given the right conditions of a weed-free sandy soil, the seeds will germinate. If water is available during the first summer they will continue to grow. This low level of seed release and survival is sufficient to maintain the population in the long term. A fire followed by summer rainfall will lead to a large increase in the population.

For germination and subsequent seedling survival of matchstick banksia, fire is not necessary, but open ground and summer rainfall are.

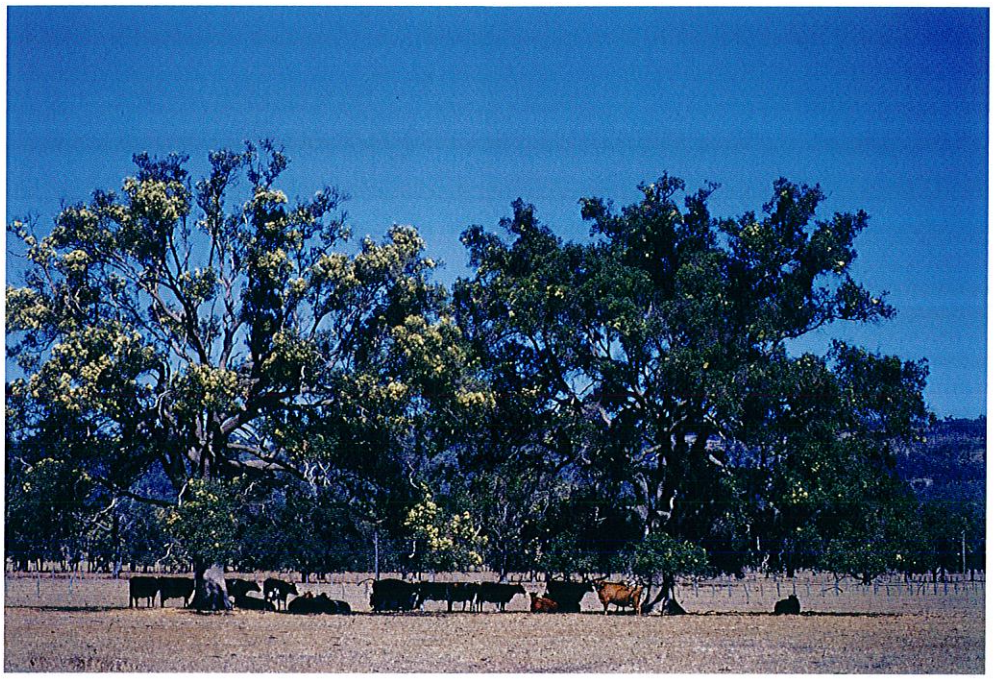
If a fire which killed all the adult plants at a site occurred, followed by a dry summer, the regenerating seedlings would die also. Matchstick banksia would then be eliminated from that site.

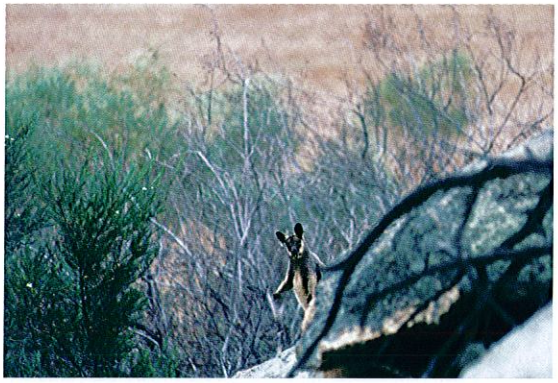


Top: *Many plants growing on naturally occuring salt areas, such as this* Conospermum eatonii, *could be used for revegetation of clearing-induced saline patches. Dowerin.* *(Penny Hussey)*

Above: *Seedlings make much more root growth than they do shoot - this is what enables them to survive our dry summers. This jam seedling is three months old. It is 2.5 cm above ground and 45 cm below ground.* *(Joanna Seabrook)*

Above right: *After 18 months protection from grazing, a dense growth of seedlings can be seen around this flat-topped yate and paperbark area. Outside the fence, grazing prevents seedling establishment. Ongerup.* *(Penny Hussey)*





Above: *Paddock trees provide important shade and shelter for stock. Waroona.*

Left: *With fencing, feral predator control and habitat re-creation, native fauna such as this rock walllaby will have the opportunity to re-occupy the sites they used to live in prior to agricultural settlement. Bruce Rock.*

Below left: *Plant alongside linear strips in order to increase their value as bush corridors. Mt. Barker.* *(Penny Hussey)*

fire for regeneration, but recent research into the matchstick banksia has shown that this is not so, in this situation at least.

This again points to the care needed when using fire to regenerate an area, especially in drier regions. Only burn a small portion of a patch of remnant vegetation at any one time and observe what happens. (See chapter 10 for design of such a burn.)

After a fire, plants regenerate in three main ways: by seeds (seeders), by resprouting (resprouters), and by both seeds and resprouting.

Each of these is discussed below.

Regeneration by Seeds

When a plant is killed by fire, new plants may regenerate from seeds stored on the plant or in the soil. To replenish this seed bank, plants must be able to reach maturity, flower and set more seeds. This time varies for different species,[13] and is best estimated by studying plants in individual remnants where they are growing. As some plants can regenerate only from seed - they are known as obligate seeders - it is particularly important that fires do not occur at a greater frequency than these plants take to establish a new store of seeds.

If normal seed production is interrupted in some way, for example by flower or seed picking, then the interval between managed fires should be increased to allow a greater time for a seed store to be built up.

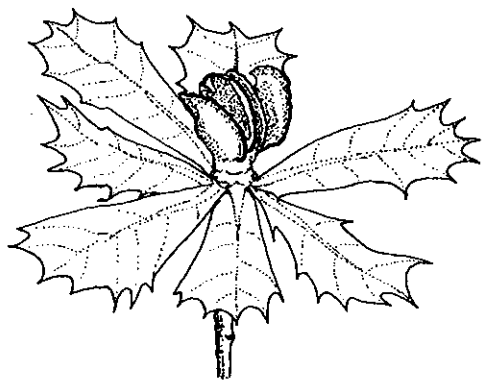
While some plant seed does not maintain its viability for long periods, that of others may. Anecdotal evidence suggests that jam seed can survive in the soil for at least 30 years or more, and there is evidence of soil-stored seed remaining viable for 170 years.[15]

In other cases, some soil-stored seed will survive several fires before germinating.

The time taken for every species of plant to build up a sufficient seed store is

Seed production by parrotbush

In many shrub species, there may not be much seed set in the first few years, although the plant appears to be flowering freely. Parrotbush (*Dryandra sessilis*) begins to flower after three to four years but does not set seed until it is eight years old. It does not reach maximum honey production until it is 12-15 years old and thus it is only at this stage that it becomes really valuable to nectar-seeking fauna.[14] Too frequent fires will eliminate this plant from the site, as happened on Donald Cochrane's farm at Duranillin, where two fires five years apart have left only one plant of parrotbush in an area that was once densely covered with them.



Thus the time between fires should not be calculated on the time to reach first flowering, but on the time to reach maturity and produce an adequate amount of seed.

unknown in most cases, and also depends on where the plant is growing, and what the seasons were like. However, a general guide is suggested as twice the time to first flowering.[16]

Regeneration by Resprouting

After a fire many native plants shoot again from buds protected beneath their bark or on their rootstocks. To do this, they use up food reserves stored in roots and stem. The mallee root - which is actually an adaptation of the stem - is an example of such a food store.

Resprouters, starting with their intact root system, have an initial advantage over obligate seeders, and may survive stress such as drought or grazing better.

However, if fires are too frequent, they do not have enough time to build up food reserves, so each resprouting becomes weaker until eventually the plant may die.[17]

Furthermore, those plants which resprout will at some stage die, and it is important that viable seed is available at that point. Our knowledge of the life history of resprouters is poor. For example, very little is known of the longevity and regeneration of our mallees, a major vegetation type. Also, some resprouters are rarely known to establish seedlings - the circumstances under which they would establish seedlings is not known, but would be important information for managers.

Regeneration by Both Seeds and Resprouting

Many plants reproduce by both methods, seeds and resprouting.

To give both seeders and resprouters an adequate chance of reproduction, the time between fires should be about twice as long as the time to maturity of the slowest growing seeders.

Flower picking, seed production and fire frequency[18]

Over 1.42 million blooms of Hooker's banksia (*Banksia hookeriana*) are picked annually from the bush around Eneabba. In this area, hot summer/autumn fires currently occur every 10-15 years. The fires kill the mature Hooker's banksia, but create nutrient-rich ashbeds on which new seedlings regenerate. Young plants start to flower at about four to five years old. Throughout the life of the plant, seed accumulates in cones on the bush. While occasional seeds are released in all years, the majority fall immediately after a fire.

Frank Obbens of Curtin University investigated the effect of flower harvesting on seed production. He found that if the flowers are removed, fewer cones can develop and so a plant subject to flower picking will have a reduced seed storage capacity. In 13-year-old plants, the picked bushes had less than half the stored seed of the unpicked bushes.

Therefore it is recommended that in picked stands, the interval between fires should be increased to 15-20 years, to allow a greater time for the plants to build up a sufficient seed store for successful regeneration. If fire occurs more frequently than that, the level of flower harvesting on each bush should be reduced.

Fire and Weeds

The presence of weeds such as grass or wild turnip among remnant vegetation increases the fire hazard, as the weeds:

- form a fine fuel which is easy to ignite and very flammable
- produce a high fuel load each year. Depending on climate and growth rate, native plants take much longer to reach the same state
- form a continuous fuel bed, permitting a fire to spread quickly. Native plants usually have gaps between them which act to slow down the spread of a fire
- may create a very hot fire at ground level.[19]

Replacement of Native Vegetation by Weeds

Frequent fires favour the replacement of native vegetation by weeds where there is a nearby seed source, such as agricultural land.

Many weeds produce copious seeds annually, and are not disadvantaged by frequent burning. In contrast many native plants are weakened by frequent fires and so are replaced by weeds. If a weed population is already present, then the disturbance caused by fire will lead to an increase in the growth of the weeds and in the extent of the infestation. This invasion will be exacerbated if the remnant has had other forms of disturbance, such as vehicle movements, and especially if the disturbance also leads to an increase in nutrients, as does stock grazing or rabbit warrens.

Ideally, weeds should be removed by some method other than burning (see chapter 6) and native plant regeneration should be encouraged.

Fire and Animals

Fires affect animals in a number of ways depending on the type of fire, the lifestyle of the animal, the condition and extent of the animal's habitat, and events before and after the fire. The immediate and medium term effects for animals living in remnant bushland are outlined in figure 9.1.

As can be seen from the diagram, any single fire will have very different results depending on the particular animal involved, the type of fire, and the surrounding vegetation.

In the case of a bush remnant which is totally burnt in a single, severe fire, the probability of some groups of animals being killed (pathway 1 on figure 9.1) is high. For example, some small birds, such as inland thornbills, are very vulnerable. A severe fire which totally consumes a remnant may result in such animals becoming locally extinct unless the remnant is connected to other unburnt areas.

Fortunately, it is more usual to find that small birds are set-back by a fire but recover reasonably well, provided sufficient resources are available. Such a situation has been demonstrated in the bush area on the northern flank of Gooseberry Hill, Kalamunda, by Ian Rowley and Michael Brooker of CSIRO.

This very detailed study of splendid fairy-wrens in an area where summer fires have been frequent, has shown that although the birds can survive the fire itself - being seen in their usual territories a day or so after the fire - the population declines in the following years, taking some time to build up to the pre-fire level.[20]

This work suggests that, for small birds, fire frequency for heathlands in the south-west of WA should not be less than once in ten years.

Other birds in the study area are not adapted to cope with post-fire conditions. The inland thornbill disappeared from the

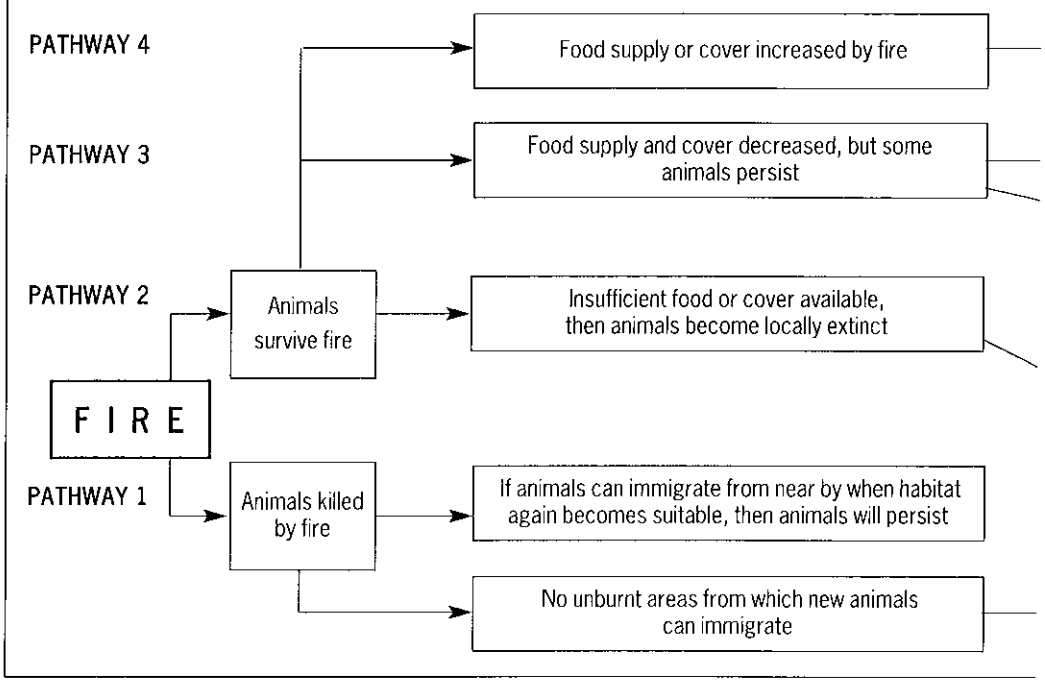
area after the fire and it took six years before one pair returned. If the fire had consumed all of an isolated remnant, these birds would have become locally extinct.

This points to the value of having somewhere for such animals to move to - if possible, remnants should not be isolated, but interconnected into a conservation mosaic.

Research workers who followed the aftermath of a severe fire in Nadgee Nature Reserve in New South Wales some years ago found that a surprising number of animals survived the actual fire.[21] While some animals escaped by fleeing, many others, such as lizards and native rodents, survived in burrows. Their problem arose when they came out looking for food. For many animals food was scarce, and the cover which usually protected them from predators was burnt (see pathways 2 and 3 in figure 9.1). Some starved, and some were taken by hawks and other predators. Under these circumstances the amount of food and cover available, which will be related to the type of fire and its extent, will determine whether or not sufficient survivors persist to reproduce and maintain the population (pathway 3), or whether the animal will go to local extinction (pathway 2). Thus a patchy fire, or one which burns only part of a remnant, is likely to have much less impact on animals than an intense fire which burns the whole of a remnant area.

Most farmers will have noticed that birds of prey are attracted to clearing burns. Presumably for these birds the column of smoke indicates a predator smorgasbord and, given that eagles and hawks can escape fires, the increased food supply which results means that for them fires are a favourable event provided they don't happen to be nesting in a tree burnt by the fire. Kangaroos and other grazing animals which

Figure 9.1 Effect of fire on an animal species: a simplified view (see text for explanation)



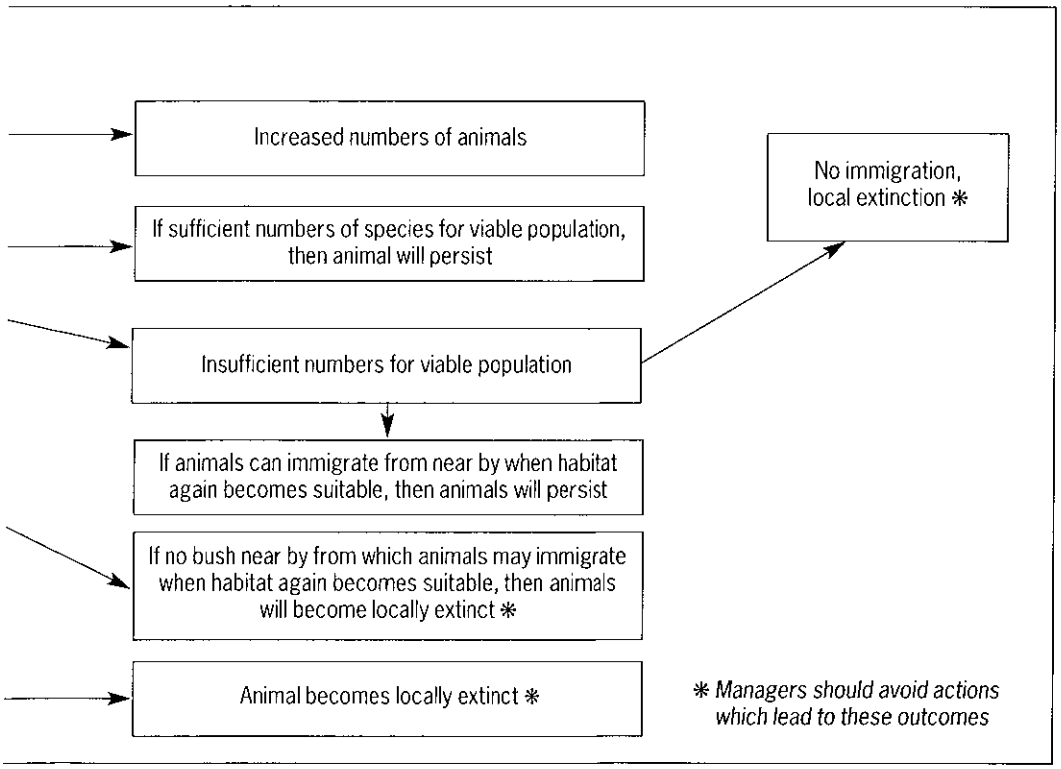
like grasses and new growth are also favoured by those fires which stimulate growth of grasses. Also, the extensive flowering of smaller shrubs within five or so years of a fire must favour those nectar feeders which have specialised in the particular plants involved.

However, a danger of post-fire flushes of growth is that they may result in such a dramatic increase in grazers, whether they be kangaroos or insects, that regeneration is severely damaged. To prevent this, burning very small areas should be avoided if this is practicable.

It is difficult to predict the outcome of any fire, particularly where remnant vegetation is involved. An understanding of the natural histories of animals is crucial to the well-directed use of fire, particularly in the case of remnant vegetation. Some animals require long-unburnt vegetation, while others are favoured by periodic fires.

The fire frequency which favours particular animals varies considerably from animal to animal. This is well shown by research on three forest animals which have quite different responses to fire (figure 9.2).[22]

Just how complicated things can get, and how this can be dependent on historic events which precede the actual fire, is shown by the woylies at Dryandra State Forest. As with the tammar, the woylie seems to require dense poison thickets as a means of escaping predators, particularly the fox. Control the fox, as is now being done at Dryandra, and woylie numbers increase dramatically without any increase in protective cover. Thus while woylies probably need to have reasonable cover, the introduction of the fox made this part of its habitat crucial. Nevertheless, in the case of Dryandra it is more cost-effective to control fox numbers than it is to provide the necessary cover.



A final example which shows the mixed effects of fires is their impact on hollows in trees and hollow logs on the ground. Many animals, including bats and 18 per cent of Australian birds, have been shown to use tree hollows for nesting or cover. Some 11 per cent of Australian birds have not been recorded nesting anywhere but hollows in trees.[23] At the same time, for many animals, such as numbats and some lizards, hollow logs on the ground are essential cover.

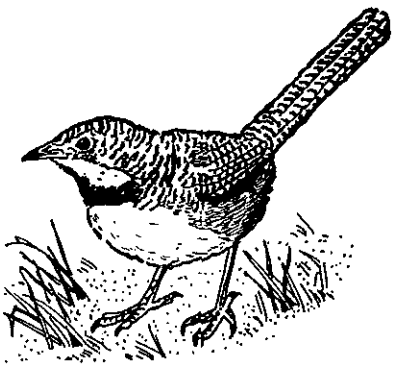
For these animals, the effects of fire can improve or destroy the habitat they require to persist. Ironically, fire consumes hollows in trees and logs on the ground, and it creates them. To maintain log- and hollow-dwelling animals on a remnant, the effects of fire on these parts of the habitat will need to be carefully considered.

Summary

Management suggestions for using fire for fauna are:

- If managing a remnant for a particular animal or group of animals, find out about their lifestyle and ensure the use of fire is compatible with them. For example, if you want to keep hollow-nesting species, ensure some of your best "hollow" trees are protected when you burn (see page 160).
- If possible, never burn the whole of one remnant at a time. Unburnt areas provide a possible refuge for food and shelter (see pathways 2 and 3 in figure 9.1).
- Where the remnant and its vegetation types are large enough, it is useful to keep some of each specific vegetation type unburnt at all times. If these areas are sufficiently large, they will provide the habitat necessary to maintain those

Unburnt thickets and the noisy scrub-bird[24]



Many small birds rely on dense shrub habitat for nesting, foraging and protection from predators, but few are as completely dependent upon it as the noisy scrub-bird (*Atrichornis clamosus*). Never common, they nonetheless used to occur around the coast from Perth to Albany but they were considered extinct when they were not seen after 1899. Rediscovery at Two Peoples Bay in 1961 was soon shown to be linked to the presence of dense, long-unburnt vegetation in the area. Careful management has allowed the population to build up - and indeed translocations to other areas have been undertaken.

The continued survival of the species undoubtedly depends upon the persistence of dense scrub, and therefore upon the continued exclusion of fire from some areas for long periods.

However, as the scrub ages it thins out, making the habitat less favourable and thus fire will be needed in some areas to restart succession.

animals which cannot survive in the early periods of regeneration.

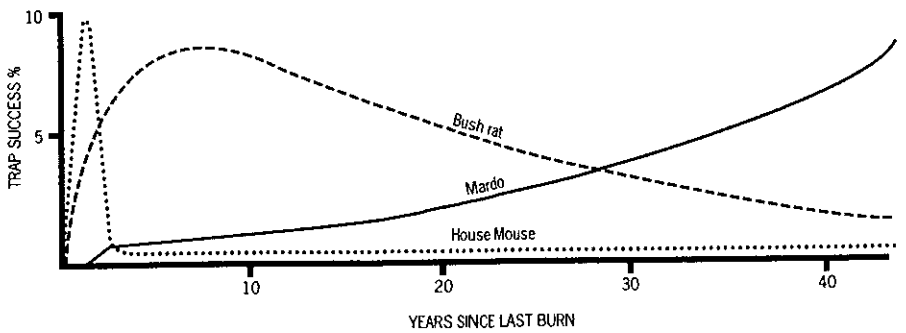
- If practicable given the size and diversity of the remnant, grazing pressure on regeneration can be reduced by increasing the burn size.
- Note any habitats, such as thick shrubby vegetation in the wheatbelt, which are susceptible to fire and ensure that not all is burnt in a single fire.
- Keep an eye on the impact of burning, and write down any effects of the fire which can be used to help the management of future burns.

The above guidelines will decrease the probability of managing a remnant into one of the boxes in figure 9.1. However, another crucial factor is increasing the effective size of remnants, particularly smaller ones, by:

- linking isolated remnants to others so that animals can move between them, thus increasing the effective remnant size
- rehabilitating degraded areas within remnants
- revegetating areas adjoining remnants where this fits the farm plan.

The fact that some of the above recommendations are acting in opposing directions is typical of the difficulties of managing remnant bush in general and fire in particular. For whatever strategy is chosen, there will inevitably be gains and losses.

Figure 9.2 Trap success of three mammals related to fire history[22]



Fire and the Spread of Disease

Many areas in WA are vulnerable to the devastating plant disease caused by the root-rot fungi *Phytophthora*. This disease is readily spread by soil carried on vehicles so, when carrying out fire management work, whether it be the construction of firebreaks, setting control burns or actively suppressing a fire, the possibility of spreading *Phytophthora* should be taken into account and hygiene measures implemented (see chapter 5).

Fire, the Soil and Nutrient Cycling

Fire has a profound effect on the soil and nutrients, as discussed in chapter 5. Organic material is converted to smoke and ash. Nitrogen and carbon dioxide go up in smoke; other mineral nutrients remain in the ash.

The intensity of the fire affects what happens to the soil. A fire, even in summer, which burns normal leaf litter may generate very high temperatures, but as the fire quickly passes on, the high temperatures do not persist for a long time. Animals in the litter and the surface layer of soil are killed, but those insulated in burrows only a few millimetres deep are likely to survive.

A different situation exists under a burning log or a heap of debris. Here the high temperatures will persist for some time and cause physical and chemical changes to the soil beneath. Areas where a log has burnt out are called ashbeds. In both wandoo woodland and karri forest the colour of the top 25 mm of soil, and its structure and permeability, are altered. It is less acid, has more soluble salts, more extractable nutrients and forms calcium

Regeneration of wandoo after fire[25]

In wetter areas such as the Darling Scarp, seedling wandoo will appear after any form of soil disturbance. However, east of the Darling Range where the main belt of wandoo forest and woodland occurs, it appears to regenerate best after fire. Here the wandoo grows on the sides and floor of broad valleys. DEC researchers led by Neil Burrows have shown that seedlings will germinate after a fire on the valley floor only in ashbeds where log debris has burnt but some seedlings will appear on the less intensely burnt areas of gravelly mid-slopes. There was better growth and a lower mortality among the seedlings in the ashbeds.

The ashbeds have an increased nutrient level and decreased competition, thus enabling the seedlings to get away to a good start. *(See photo on page 129.)*

carbonate. In addition, it is sterile; all living creatures, even in burrows, have been killed. Ashbeds provide important conditions for the regeneration of a number of eucalypts, including karri, wandoo[26] and salmon gum.

Fire and Soil Seed Storage

The seeds of many plants such as woolly-bush (*Adenanthos cygnorum*) and wattles like prickly moses, are stimulated into growth by the intense heat of a fire. Their seeds are carried down into the soil by ants, and germinate if sufficient heat reaches them. (They may, however, germinate under other circumstances such as scarification of the seed coat during soil disturbance, for example by vehicles.)

Because of this effect, a ring of such plants is often seen growing not on, but around the edge of, an ashbed.

The Use of Fire

In areas where there is danger to life and property from wildfire, for example adjoining houses, fuel reduction for safety purposes may be a vital consideration, and pre-eminent in determining the fire regime. Nevertheless, conservation of the natural community should be an objective of bush management, and should be included in fire responses and management plans.

In areas where the threat to life and property is not so immediate, conditions for burning can be selected to produce maximum benefit to the ecosystem.

The impact of fire on isolated areas of remnant vegetation is so critical that its use should be carefully planned.

Draw up a fire management plan:

- set objectives
- record relevant information
- draw up a plan of action
- record the results.

Setting Objectives

Fire should only be used in remnant vegetation for one of two reasons:

- as a way to reduce a fire hazard
- as an ecological management tool.

Remember that regeneration after fires will vary from year to year, so only put a trial burn through small areas in any one year. Then if drought or some other unexpected event does strike, not everything will be lost. (See chapter 10 for a plan.)

Fire Hazard Reduction

The presence of flammable material does not constitute a fire hazard of itself. A hazard only exists when there is something of value nearby, such as a building or a fence which could be burnt. There must also be a chance of ignition taking place. Other fire behaviour factors such as the rate of fire spread and flammability are important also, as they reflect the difficulty of fire suppression and therefore the potential to cause damage or threaten the safety of fire fighters.

Fire Threat Analysis

To assess a fire hazard, an analysis of the risks and values should be undertaken.

Risks

Likelihood of ignition: Fire is unlikely to start naturally (for example from lightning) in a small remnant. However, fires may enter from adjoining land, for example, escapes from a stubble burn.

Type and quantity of flammable material: Most plant material will burn, but fine fuels burn best. Leaf litter, fallen branches and dried grass all contribute to fuel loading but grass is the chief concern, as it is extremely flammable. The greater the amount of fuel, the fiercer the fire is likely to be.

Continuity of fuel bed: A fire will spread less quickly if there are gaps between the plants. This is the principle behind the installation of firebreaks.

Topography: Fires spread rapidly up steep slopes, and are more difficult to suppress in rough or steep topography.

Frequency of hazardous fire weather and availability of suppression forces: These vary from region to region, but should be considered when evaluating risk.

Values

Life and property: Consider what could be at risk from fire in the remnant vegetation.

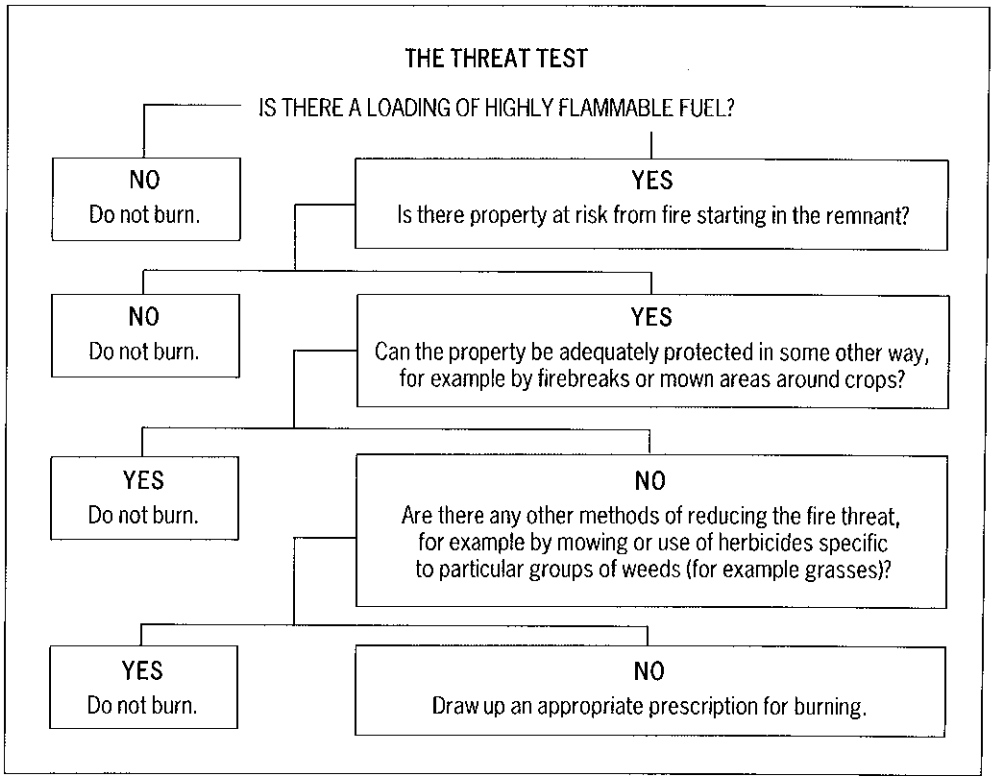
Conservation: The effect of fire on native flora and fauna depends on the vegetation type and the fire regime.

Abatement of Fire Hazard

If it is decided that the remnant vegetation does pose a fire hazard, there are several methods which could be used to abate it:

- removing heaps of flammable debris
- removing grass fuel by herbicide
- reducing the density of fuel by mowing or slashing
- creating a wider firebreak in the cleared land around the remnant, or
- burning to remove the fuel load - prescribed or controlled burn.

To decide whether fuel reduction burning for fire hazard abatement should be undertaken in remnant vegetation, use the "Threat Test", developed by the Roadside Conservation Committee for use on roadsides.[27]



The use of fire to abate fire hazards should be confined to those areas where distinct hazards, high ignition risks and high values can be identified. Although prescribed burning is the most economical solution for large areas, other methods, as listed above, could be considered for remnants, especially if a controlled burn would conflict with ecological management objectives.

The use of fire is a contentious topic and is likely to remain so given the destructive potential of fire and our lack of knowledge concerning its use. Advice should be sought from members of the local Land Conservation District Committee, or Bush Fire Brigade, the Bush Fires Board or DEC.

Fire for Ecological Management

Fire management for nature conservation involves ensuring that fires do not occur more frequently than the time needed for all plants to reach adequate reproductive capacity, and ensuring that an adequate range of habitats for fauna is provided.

Within a large remnant or a group of smaller ones, the fire regime is usually planned to be as varied as possible to encourage community diversity. It is assumed that, if vegetation health and diversity is maintained, animals will continue to use the area. Alternatively a fire regime can be designed to favour selected segments of a community, for example an endangered species.

Aim for a Mosaic

Under a natural situation, the landscape would have contained a mosaic of different vegetation types and ages since the last burn. These would have created many different habitats for fauna.

If the remnant is large enough, divide it into sections, treat them to different fire regimes, and attempt to recreate this mosaic effect. Try to ensure that the burnt country is, so far as is possible, contiguous with unburnt areas.

Where a number of smaller remnants can be linked together by bush corridors, it might be possible be treat them as a larger unit and create a mosaic burn by treating each one separately.

Draw up a Fire Management Plan

Because fire is an unpredictable tool, and because successful regeneration after fire depends on adequate follow-up rainfall, it should be used very carefully indeed. When in doubt, don't burn, or burn only small sections!

If a fire does occur, whether deliberately lit or not, it would be helpful for future planning if a record of fire weather conditions and effects was kept. A sequence of before and after photographs is extremely valuable (see page 41).

For the fire management plan, the following information could be useful:

- *Are the major species setting seed?*
  check the plants in the remnant to see if sufficient time has elapsed since the last fire to ensure ample mature seed is available
- *Are weeds present?*
  control should be undertaken; see chapter 6
- *Are rabbits present?*
  control should be undertaken; see chapter 8
- *Are kangaroos common?*
  fencing or control of numbers might be needed; see chapter 8
- *Is Phytophthora dieback present or possible?*
  hygiene measures should be practised; see chapter 5
- *Is Declared Rare Flora present?*
  a permit to take must be obtained through DEC

- *Are special fauna habitat features, for example hollow logs, present?*
  design the burn to take account of them
- *Are any areas buried under wind-blown sand?*
  do not burn
- *Does the prevailing wind blow in weed seeds?*
  consider leaving an unburnt buffer to trap weed seed
- *Is an intense fire needed to crack dormancy?*
- *Would heaping be valuable?*

The plan should be written for the long term, with actions such as weed and rabbit control spread over several years if necessary. Monitoring should be an integral part of all management actions, so that the effect of the work can be assessed.

Special Management Considerations

Herbivore Control

Young seedlings are tasty, and excessive grazing will severely limit the success of a regeneration programme.

- In no circumstances should stock be allowed on the area.
- Rabbits are exceptionally damaging, especially at the start of the dry season when lush, green feed becomes unavailable. Resident rabbits should be controlled prior to the burn taking place, and follow-up control should be undertaken to keep the area as rabbit free as possible (see chapter 8).
- Kangaroos preferentially graze recently-burnt vegetation, especially native grasses. If a small mosaic burn is being practised in a group of remnants that are included in the home range of a group of grey kangaroos, it is a good idea to consider control measures (see chapter 8) or fence out the regenerating area for the first couple of years.
- Insects and other invertebrates such as grasshoppers and red-legged earth mites can cause considerable damage to regenerating vegetation. If insects are a problem, then consideration should be given to burning larger areas if this is practicable. This approach may decrease problems with insects given that very small burn areas can become a focus of attention for large populations of insects.

Protection of Hollow Logs and Habitat Trees

Ideally, remnants should be managed to provide a range of animal habitats including habitat trees. These old trees, with their many hollows, are used extensively by many different animals. Hollow logs on the ground are also an important food source as well as shelter. Fires are believed to be one factor stimulating hollows to form in trees, and almost any fire will burn down some trees which will provide an on-going supply of hollow logs. As fires also burn ground logs, any one fire may cause both a loss and gain of habitat trees and hollow logs. The balance of loss and gain will depend on the type of fire involved.

It is difficult to retain all habitats on small remnants, and in some cases choices may have to be made. If it is decided to manage a particular remnant for hollow-nesting birds, then it may be desirable to protect at least some habitat trees during a prescribed burn. To protect a habitat tree:

- remove any debris that has accumulated against the trunk
- rake a cleared space around the habitat tree to prevent the fire travelling through the leaf litter to it, if conducting a heaping burn nearby (habitat trees are often excellent as seed trees)

- alternatively, douse the base of the tree and its surrounds with fire retardant just prior to burning.

If an objective is to keep hollow logs as habitat, they can be protected in a similar way.

Note that if habitat trees do catch alight, they are difficult and sometimes dangerous to extinguish.

Areas of Wind-deposited Soil

Fire should never be used as a regeneration tool on these areas, as normal post-fire succession will not occur.

- Germination from seed stored in the soil will fail.
- Regeneration from buried rootstocks will fail.
- Germination of seeds on the drift soil surface will be outcompeted by weeds or will die during summer due to the water repellence or low water-holding capacity of the soil they are growing in.

Regeneration of these remnants is a difficult task unless the underlying cause - the soil erosion on adjacent land - is treated first.

Regeneration Techniques

Burning Individual Trees

A fire which burns and kills one individual tree can sometimes lead to regeneration on the site. This can be seen in natural stands of salmon gum. But beware - it doesn't always work. Unless a tree is clearly already unhealthy, this technique is probably a gamble.

Burning Small Patches

Burning small patches of vegetation can lead to good regeneration. York gums under stress from salinity were burnt by Kingsley Barnes at Morawa, followed, in this case, by flooding of the site. Very healthy regrowth occurred.

Other examples are provided by Kelly O'Neill of Ongerup who has had good success regenerating isolated York gum remnants and long-grazed moort (*Eucalyptus platypus*) windbreaks by burning them with as hot a fire as possible in late autumn. These 20 m wide strips, isolated within paddocks and subject to grazing for 60 years, were fenced prior to the regeneration work. Clover-leafed poison, not seen in the area for 30-40 years, also appeared after the fire.

Again, burning a portion of a remnant and observing what happens is very important. As the next example shows, results may vary from year to year depending on the particular circumstances of the fire involved.

Fire and swamp mallet plus good following rains equals regeneration

At Ongerup, Kingsley Vaux has an unused road reserve running through his property. Always fenced on one side, it was fenced on the other in 1982 to encourage regeneration. The trees appeared to be healthier but the understorey did not regenerate. In 1985 a fire escaped and burnt a group of swamp mallet (*Eucalyptus spathulata*), killing them. Subsequently a thicket of young swamp mallets and shrubs, including a wattle that had not been noted in the area, has come up on the site.

Warning - when the same trick was tried on a second group of trees, it was followed by a very dry year and neither seedling nor resprouting regeneration of anything survived. *(See photo on page 130.)*

Heaping

When a heap of debris burns, an ashbed is produced which may be important for regeneration in some vegetation types. It is known to work for jarrah, karri, York gum and wandoo, while salmon gums - notoriously difficult to regenerate - have been observed to germinate and survive in ashbeds at Coorow, Northam and Trayning.[28] Other eucalypts known to respond to ashbeds are gimlet (*Eucalyptus salubris*) and red morrel (*Eucalyptus longicornis*). Wattles, gastrolobiums and other peas also germinate well around ashbeds.

In heavily grazed remnants, heaping may be the only way to create sufficient fuel for a suitable fire to occur.

Note: any seeds held in fruits on branches in the heap will be totally consumed. If branches have viable seed on them, don't include them in the heap; retain and spread out so that the seeds will fall out onto the ashbeds after the fire. This technique is known as "brushing" (see chapter 10).

How to use heaping in remnant vegetation:

- create a heap of brush, off-cuts and small branches
- do not burn hollow logs (potential den sites for fauna)
- spread the heap into a long narrow shape (this maximises the edge effect for wattle and pea germination)
- make a heap no more than 50 cm high to create an effective fire
- burn when an intense fire will result - suggest autumn
- do not heap against living trees or shrubs; the prolonged intense heat could do them serious damage
- place heap, if possible, in a weedy area, not on top of healthy native ground flora, since the soil is sterilised beneath the heap.

A source of seed must be present to fall on the ashbed. This would normally be from existing trees, but seed can be collected and spread manually if wished.

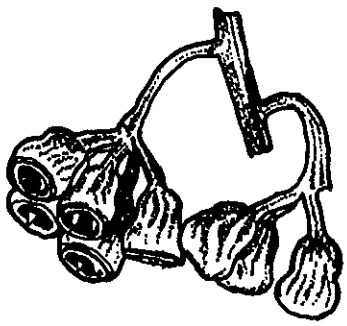
When to use heaping for regeneration in remnant vegetation:

- in woodlands - wandoo, powderbark, salmon gum and York gum - use in clearings alongside, but not directly under, the crown of mature trees which would inhibit subsequent seedling growth
- where a dense thicket of wattles or peas is desired, perhaps for fauna habitat
- in very degraded areas it is especially useful, as it may stimulate the germination of plants thought to have disappeared from the site.

Growing brown mallet on an ashbed

Donald Cochrane of Duranillin wished to establish a stand of brown mallet. After a fire had burnt through a remnant on his property, he scattered brown mallet seed onto the ashbeds. Germination was excellent and a dense stand of poles is developing.

The brown mallet plantations at Dryandra were established this way.[29]



Terri and Dayle Lloyd of Dumbleyung decided to encourage regeneration on a granite outcrop that had been grazed for many years and had almost no native plants remaining. After fencing to exclude stock, Dayle made a bonfire of some "unsightly dead stuff". Developing around the edge of the fire site is a thicket of *Acacia trigonophylla*, which used to be common at the site before grazing apparently eliminated it.

Removal of Weed Layer Prior to Direct Seeding

Direct seeding is only effective if the seeds come in contact with the soil. When attempting to seed understorey into a remnant which contains trees but only a weedy ground layer, fire can be used to remove the weed layer prior to sowing. But beware: some weeds are favoured by fire, and subsequent weed control may be necessary. (See chapter 6) Fire used for weed control is most effective just after the first rains.

Buffers

If the remnant is large enough, consider leaving an unburnt buffer between the burnt area and undesirable influences from the surrounding countryside. Weed seeds, fertiliser drift and insecticides, among other things, can be trapped by dense shrubs and this keeps the interior of the remnant less disturbed. A belt of planted trees outside the remnant may fulfil the same function.

Chaining

Occasionally it is suggested that heath and scrub vegetation be chained prior to burning.

In a remnant, chaining and burning are not recommended for a number of reasons, including:

- piling up the vegetation which contains viable seeds creates a more intense fire, killing instead of simply releasing seed
- viable seeds are destroyed in the fire - there is loss of seed for regeneration
- the process uproots rootstocks. Even if any of these survive being burnt, regeneration from them will be severely impeded
- the soil disturbed in the chaining process is an ideal site for weed invasion
- it may, however, be valuable to pull out already dead plants, such as jam trees, so that they create ashbed conditions during the fire.

Legal Aspects

Because fire is potentially so damaging, its use is regulated by legislation and it is important to understand the relevant laws.

The Bush Fires Act

Control of bush fires in WA is provided through the Bush Fires Act and its Regulations.

The Bush Fires Act sets up a controlling body, the Bush Fires Board, to administer the Act State-wide and advise the government on ways to safeguard the community from damage by fires.

Day-to-day administration of fire control measures and maintenance of bush fire brigades is delegated to individual Local Government Authorities. Local Government Authorities also appoint Bush Fire Control Officers (usually volunteers) who have a fire prevention as well as a fire suppression role.

In urban areas, the Western Australian Fire Brigade has responsibility for fire suppression. Bush fire prevention measures, however, remain the role of the Local Government Authority.

While the Bush Fires Act prescribes basic rules for fire protection and the use of fire it also allows considerable local discretion in their application, enabling Local Government Authorities to suit their local fire rules to the immense variation in

fire hazards which exist in a State the size of WA. This makes it important to consult with the Local Government Authority or local Bush Fire Control Officer so as to become familiar with local fire rules.

Prohibited and Restricted Burning Times

The State is divided into 13 zones for the purpose of determining the times of the year when prohibitions and restrictions on the use of fire will apply. All Local Government Authorities are located within a specified zone according to climate and fire risk determinations. As with the conditions which apply to the use of fire, the dates when the prohibitions and restrictions apply may be varied locally according to seasonal conditions.

Check with your Local Government Authority before using fire.

During Prohibited Burning Times fires are, with very few exception, prohibited. Within Restricted Burning Times the use of fire is controlled through a permit system. Permits may be obtained through the Local Government Authority or local Bush Fire Control Officer. One of the conditions applying to a permit to use fire is that the neighbours are given due notice of your intention to burn. If you plan to light the fire within three km of State Forest a Forest Officer from DEC must be notified as well.

During times when the fire danger for a district is Very High or Extreme, permits to burn are automatically cancelled and may only be validated by a Fire Weather Officer appointed by the Local Government Authority.

Fire Suppression

Owners or occupiers of land, on becoming aware of a fire on the land, must immediately take measures at their own expense to suppress the fire. In other words, the basic responsibility for fire suppression lies with the landholder.

However, WA is served by a widespread and effective Bush Fire Brigade system. Bush Fire Control Officers and Brigades have extensive powers to enable them to perform their duties, including powers to enter land, use water, create firebreaks and cut fences. They have immunity from liability provided they are acting in good faith.

When fires burn on, or near, Crown Land, a Forest Officer may elect to take control of fire suppression.

Firebreaks

Local Government Authorities may require landholders to provide firebreaks or remove fire hazards from their land. A notice to this effect may be published annually or may be a local By-law. Notices encourage landowners to negotiate alternative types and locations of firebreaks in circumstances where land degradation may occur as a result of rigidly following the standard notice. It is most important that landowners understand and take advantage of this option.

In event of default by the landholder, the Local Government Authority has the power to enter the land and provide firebreaks at the landholder's expense. Penalties (Infringement Notices or Fines) may also be imposed.

Common Law

Notwithstanding that a person obeys all of the provisions and conditions of the Bush Fires Act, if fire is used and it escapes from the property, that person could be answerable for the damage caused.

The degree of culpability will naturally be assessed by the Court according to the circumstances which prevailed at the time but it is important that all persons using fire understand the obligation that they have to keep the fire under control and on their property.

10 Regeneration and Replanting

- Improving habitat to increase carrying capacity
- Regeneration of degraded bush
- Revegetating areas adjacent to remnants
- Connecting remnants with revegetation corridors

The ability of remnants to maintain a range of plants and animals may be improved by increasing remnant area, or by improving the quality of the bush habitat.

Some ways of increasing area include connecting remnants with corridors and revegetating areas adjoining native bush. The quality can be improved by managing the habitat to increase its carrying capacity and regenerating degraded bush.

Each of these is briefly discussed below. Detailed information concerning revegetation and regeneration techniques can be found in other publications; therefore it is recommended that those seriously setting about revegetation consult the many references on this subject (see chapter 11).

Improving Habitat to Increase Carrying Capacity

Sometimes the resources of remnant bushland can be improved for wildlife, particularly animals, by specific management actions to improve habitat. The most obvious way of doing this is to increase the range of available shelter or food resources. This could be done by burning part of a remnant to increase a particular food resource, or adding nesting boxes where tree hollows are rare. These and other examples are covered more fully in chapters 7 and 9.

These methods of increasing the capacity of a remnant to carry more wildlife, or a greater variety of wildlife, are generally difficult to implement. Too often the impact of management techniques is unpredictable, their likely consequences unknown, and the scope for undertaking risky experiments is small. A comparatively large area is required to try out new ideas so that the effect of mistakes is not local extinction of species.

Regeneration of Degraded Bush

Regeneration is used here to mean the process of re-establishing a native plant community similar in composition and diversity to the original vegetation. Natural regeneration is when this happens without intervention by humans.

Four things are essential for regeneration to occur:

- no grazing by stock, and minimal grazing by other animals
- minimal weed competition
- a source of seed or other reproductive material
- a suitable seed bed.

Also desirable:

- a natural soil profile
- a natural level of soil nutrients
- a favourable climate, particularly good following rains, at least for the first year.

Sometimes a stimulus for seed-release and germination, for example a fire or flood, will also help the process.

These issues are discussed below.

Grazing

Young, fresh shoots are very attractive to most grazing animals, including sheep, insects and kangaroos. While these animals undoubtedly appreciate our efforts, they often leave little for us to appreciate.

To control grazing:

- fence rehabilitation areas from domestic stock
- control rabbit and kangaroo numbers if necessary (see chapter 8)
- if a locust plague is forecast do not regenerate that year, or alternatively, regenerate plant communities (for example jam and York gum) which are less susceptible
- control insects and other invertebrates, for example red-legged earth mites, as necessary.

Note that many eucalypts are strongly competitive and young plants will not survive under adult trees. Even planted seedlings may have their growth severely reduced. Therefore, fencing for regeneration purposes should be set one to three tree heights out from the crowns of the trees, where new trees are required.

Weed Control

Native plant seedlings have great difficulty establishing if there is competition from weeds.

Weed control measures should be started in the year prior to the main effort at regeneration and continued, if necessary, after seedling establishment. A method appropriate to the site and weeds present should be selected (see chapter 6).

Availability of Plant Reproductive Material

Plants may reproduce from either seed or from vegetative material. Examples of the latter include resprouting from mallee roots, suckering from roots, and growing from tubers, as do orchids.

While vegetative parts may be important in regeneration, seeds and seedlings are generally used because they are less difficult to work with. Therefore we have concentrated on seeds and seedlings here.

Seeds

Parent plants on site should mean that some seed is available, but eucalypts especially do not always have good seed years, and other plants may need a specific action such as fire to promote release of the seeds (see page 168).

On any site some native plant seed may be stored in the soil. Jam, for example, is well known for suddenly appearing many years after all visible plants have been removed. On the other hand, some seed loses its viability very quickly - WA Christmas trees' seeds germinate in the winter following their production, or not at all. To be sure, it is best to use freshly collected seed on each project.

If grazing has killed most of the understorey, it is unlikely that there will be much left in the soil seed-bank except for long-lived seeds such as jam. The plants are no longer there to produce an annual seed crop, while ants and other predators will have removed most soil-stored seed. In addition, the compaction produced by stock hooves, combined with erosion of the top soil and leaf litter, will also contribute to seed loss. This is very much worse on sloping sites. Thus the land manager will have to add seed during the regeneration project.

Use Local Seed

It is important to conserve the local genotype as this will have inherited characteristics to cope with the local environment. York gum, for example, is a very widespread tree, but seed from the south of its range does not grow as well when planted in the north, and vice versa.

Seed merchants use the term "provenance" to describe the location where seed was collected so, when revegetating in association with remnant vegetation, it is important wherever possible to use local provenance seed.

For the regeneration and extension of remnant vegetation, local species should be used to protect the genetic resource. However, in many areas where revegetation is needed on farmland, the environment is

How local is local?

Close to a nature reserve, locally collected seed should be used so as not to compromise the local genotype, and in all natural areas, local seed is likely to grow best. But how local is local? Some plants may be alike over large distances; others vary considerably. In Kings Park, for example, the pearl flower (*Conostephium pendulum*) has been found to have a slightly different genotype every 100 m[1]

As a general guideline Main Roads, which undertakes revegetation work in all areas of the State, defines local provenance seed as that collected within 15 km of the site to be revegetated. When working in association with existing remnant vegetation, it's as good a rule of thumb as any.

so changed - by salinity, for example - that the original vegetation would no longer grow well, although seed collected from plants growing on local, naturally-occurring saline areas could be used. In that case, the best plants for the job should be selected, and, with some thought, additional ideas to enhance nature conservation value can be included in the design.

Seed Collecting

For best results in any regeneration project, seed should be collected in the local area from plants growing in a similar soil type and plant community. Note that seed may only be collected from other people's land, including government (Crown) land, with the permission of the owner or manager. Picking of seed for commercial purposes requires a licence from DEC.

In general:

- Locate potential seed plants and collect as closely as possible to the time you intend to seed (usually it will be the summer prior to seeding).
- Choose plants growing in a group, as isolated plants (for example paddock trees) are likely to have less seed set due to fewer pollinators and lower viability due to inbreeding.
- Remove seed carefully, doing minimum damage to the plant.
- Take less than half the seed from any one plant (unless it is a windthrow).

Seeds which shed annually, for example everlastings, wattles and peas, grevilleas, verticordias, pop flower, and some eucalypts:

- Collect as soon as they are ripe - between Oct/Dec depending on the weather. Fruits will change colour to brown and become brittle and should be collected as they begin to open or fall naturally.
- If collected at the right stage, a vigorous thrashing of the branches will bring down a load of seed (and insects!) upon a tarpaulin spread beneath the plant.

Seeds which are held in woody fruit on the plant, for example sheoaks, banksias, calothamnus, hakeas, beaufortia, eucalypts, melaleucas:

- Collect at any time but it is best in summer when the fruit can be air-dried to extract the seed.
- Place banksia and dryandra fruit base down among the embers of a small fire. As the follicles open up, use barbecue tongs to take the whole fruit out of the fire and shake to remove the seeds. Repeat until there are no more follicles to open. Do not leave too long, or the seeds will cook!

Seed Drying

- Air-dry seed in a warm, dry place, either in paper bags or spread out on sheets of paper or a tarpaulin. (Do not use plastic bags or the seeds will go mouldy.) Depending on air temperatures, it will take up to three weeks for the fruits to open.
- Remove seed for storage and retain fruits and branches for brushing.

Seed Storage

- Store dry seed in sealed, clean, dry containers such as jam jars or plastic tubs.
- Add a little insect control dust.

Breaking Dormancy

Wattles and peas need mechanical scarification or heat treatment before they will germinate. The easiest method is to pour boiling water over the seeds, leave for a few minutes, then strain and sow.

Alternatively, they can be air-dried after the boiling and then stored ready to be sown

at a later date. In that case, the boiling water breaks the dormancy but drying does not let the seeds take up enough water to start germination.

Site Preparation

Site preparation should be done in the spring/summer preceding the year in which the regeneration effort is to commence and must be given time to settle in some cases. This is most important in hard-setting soils where large clods are thrown up and entire seedlings can disappear down into the voids below.

Extra moisture may be all that is needed to stimulate germination of some seeds. The creation of low mounds and banks (see figure 10.3) can trap seeds and water at the same time. Logs laid on the contour are also excellent seed traps and help to reduce surface wind speed.

Hard packed soil will not hold seed or water, neither will it be easy for seedling roots to penetrate.

In a natural situation, the activities of native animals are important in creating a seed-bed. For example, echidnas break up the ground and leave behind rough, disturbed areas very suitable for seedling germination.[2] Cultivation on the contour, including deep ripping, can achieve the same effect on a large scale and it is especially valuable where soil compaction has been created by stock or machinery. A ripline alone can be a suitable site for seedling growth, as demonstrated by the vigorous hedge of young trees growing on top of Telecom cables in the eastern wheatbelt.[3]

Seedlings put much of their initial growth effort into root development and only if this proceeds satisfactorily will they survive the dry summer. A three-month-old jam seedling dug up near York by Adelphe King

Seed orchards[4]

A seed orchard is a plantation of native trees or shrubs grown principally so that the seeds can be collected. In WA, the Eastern Hills Branch of the WA Wildflower Society pioneered the idea, spurred on by long-time member Joanna Seabrook, so that they could assist Mundaring Shire by providing local native plants for revegetation after roadworks or other disturbance. The Shire made an old gravel pit available and did the mechanical work necessary for ground preparation. Plants known to grow well from seed were sown in rows and harvesting began by the second year. After ten years, the seed orchard, which now occupies about half an acre, annually supplies about $2 000 worth of seed to the Shire.

This is an excellent project for schools or community groups.

in January 1992 had two cm above-ground growth and a main root at least 45 cm deep (it broke at that depth and could no longer be followed - see photo p147).

Some plants germinate best around ponds created by floods. Flooded gums (*Eucalyptus rudis*), river gums, yates, York gums, saltwater paperbarks (*Melaleuca cuticularis*) and swamp sheoaks respond in this way. Creation of a water-holding mound creates the right conditions - provided there is sufficient rain. Where flooding is a problem, mounding will help prevent waterlogging of seedling roots.

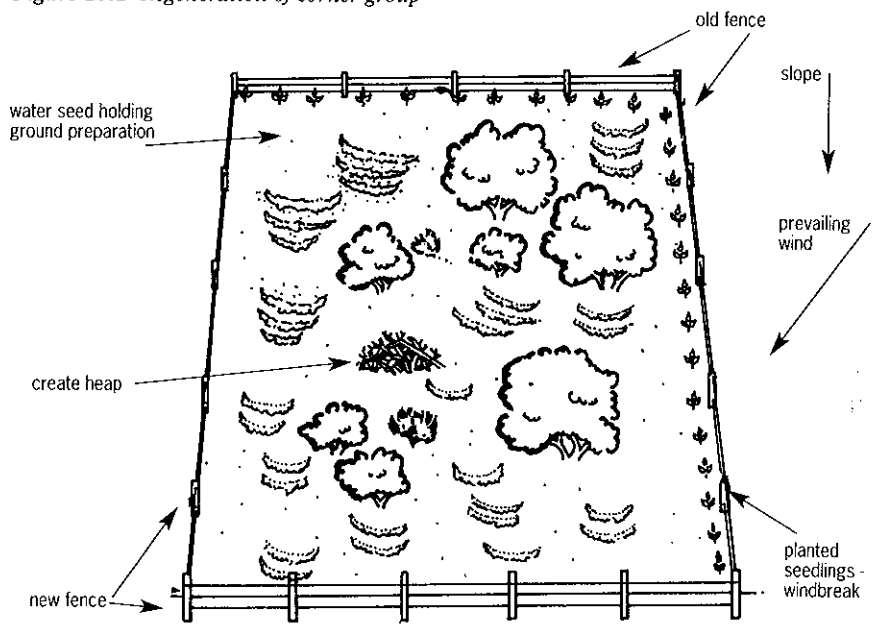
Another technique that is useful to encourage seedling establishment, especially on difficult soils subject to surface movement by wind, is gravel/rock chip mulching. Work done by Main Roads has demonstrated that a layer of gravel or road metal over the soil surface, especially if it is inclined to be loose and light, acts as a mulch during regeneration, conserving moisture and inhibiting weeds.[5] Trayning Shire found out about this by mistake, when a fine stand of salmon gums came up through the remains of a blue-metal heap![6]

The layer should be loose, not compacted and need only be one chip thick. Seeds can be sown directly onto it and their survival and establishment will be greatly improved.

Where this is not possible in sandy sites, a porous windbreak should be erected prior to seeding. This could be a planted line of shrubs, or even a windrow of brush debris. A line of remnant vegetation, such as a road verge, could make a good windbreak for this purpose, but remember that seedlings will not establish under the crowns of existing trees.

Note also that direct seeding does not establish well on sandy soils deposited by recent wind erosion.

Figure 10.1 Regeneration of corner group



Direct Seeding

Seed of plants not present on the site (especially understorey) can be seeded directly into the area. This can be done mechanically or by hand, depending on personal preference and the area involved. Note, however, that success with this method is dependent upon rainfall and it may totally fail in poor years. In general, the technique has been most successful where annual rainfall exceeds 400 mm.[7]

The direct seeding method has several advantages over the planting of seedlings:

- it is far less costly in time and labour than planting seedlings
- large areas can be sown rapidly using readily available machinery
- a mix of trees, shrubs and ground layer can be sown at once, thus establishing an approximately natural community
- the mix can be varied for different soil types and topographic positions
- the plants grow naturally, with deep roots, and respond better to climatic extremes - natural selection will remove the weaker plants
- the plant community that develops has a natural-looking appearance.

But success is affected by the weather:

- In dry years, total failures can occur. Because of this uncertainty, it is a good idea to sow some seed which has not been treated to break dormancy. This will be capable of germinating in future seasons.

Site preparation - the site should be:

- weed-free - or weeds controlled, preferably starting the year before seeding
- deep-ripped if heavily compacted
- roughed up so that seed can lodge in crevices.

Seed quantity:

- use the right amount of seed depending on the seed type and the result desired. Quantities of seed from 0.5 to 4 kg/ha have been recommended
- heavier mixes are those with half to three quarters of heavy-seed types such as wattles and peas. Lighter mixes have only light seeds
- bulk the seed with an inert agent such as clean dry sand, vermiculite, bran or even chick pellets.

Timing:

- seed should be sown as soon as possible after the first rains to give the longest establishment time unless waterlogging is a problem, in which case the seed could be sown later.

Sowing the seed:

- by hand, mix one handful of seed cocktail into three-quarters of a bucket of clean sand. Spread evenly over an area equivalent to a quarter of a tennis court
- by superspreader or combine. The superspreader gives a more natural effect. (A five-metre-wide combine travelling two kilometres covers one hectare.)
- by direct seeding machine.

Difficult sites:

- sites prone to waterlogging and salinity cannot be sown directly unless mounds are constructed
- sites with light soils will destroy seedlings through sandblasting, unless a windbreak of some sort is provided. Slight compacting of light soils, for example by tractor tyres, directly after seeding can increase the germination percentage in these soils
- sites with hard-setting soils do not respond well.

Burying the seed:

- with ridged ground, seed will fall into crevices and covering will not be necessary - to be most effective, seed should be sown immediately after roughing up
- with machines, chaff bags could be dragged behind to lightly cover the seed
- note that eucalypts, melaleucas and other small seeds will not germinate if buried deeply.

Maintenance:

- control grazing, fence out stock and control rabbits
- control weeds. If weed control was undertaken thoroughly in the first place, and the seeds were planted thickly enough, weed establishment should not be a problem. If it is, treat accordingly (see chapter 6)
- control insects. Insects may be a problem; check frequently and treat as necessary.

Remember that even when you do everything right, if the weather does not co-operate there will be poor germination and poor establishment.

Brushing

This technique is part way between natural regeneration and direct seeding. It involves laying seed-bearing portions of native plants directly onto the prepared ground, allowing seeds to fall from them. This material protects the seedlings which grow up through the branches, and also contributes leaf litter and humus to the soil. It is especially useful on sites subject to wind erosion, as it helps lift wind above the surface.

Plants which hold their seeds in hard, woody fruits that open as the branch dries are especially valuable for this technique. Examples include eucalypts, melaleucas, calothamnus, bottlebrushes, tea-trees, sheoaks and some banksias and hakeas. The branch holds the fruit above the ground so that the seeds can fall out. If only fruits are spread, they can become embedded in the soil, trapping the seed within them.

It is also a very useful way to salvage seed from mature trees blown down during a storm or knocked over during roadworks. As soon as possible, cut off seed-bearing branches from the tree, lay them on a tarpaulin, and transport them to where regeneration is to be encouraged. (But remember that seedlings will not be able to compete with established weeds or with mature trees.) Note also that for the sake of genetic variety, seed from several parent plants should be combined in the seed mix at any site.

Topsoiling

If there is sufficient interest, bush topsoiling can be tried. This involves collecting some buckets of topsoil from a weed-free patch of bush very similar to the area it is hoped to regenerate and distributing it into a suitably prepared site in the new area. Of course, it is important not to damage the bush area while collecting topsoil, and great care must be taken not to transport *Phytophthora* dieback.

On a large scale, a similar technique is used extensively in mining rehabilitation. In this instance the topsoil from a proposed mine is stripped and carried to an area where mining has ceased. There it is spread to help with rehabilitation. It not only brings in seed, but also vegetative parts of plants, leaf litter, humus and soil micro-organisms, all of which could be sparse in the regeneration area.[8]

An important aspect of this process is that fungi are brought in. They form mycorrhizal associations with native plants. These are important to assist the plant with mineral nutrient uptake and could well be

missing in degraded remnants. Some fungi are specific to particular plants so, for example, if reintroducing broombush understorey to a salmon gum remnant, some buckets of topsoil from underneath a healthy stand of broombush, thinly scattered onto the soil just after direct seeding, should be beneficial. Alternatively, if planting seedlings, spread a handful of the topsoil around each planted seedling.

Seedlings

Site Preparation

Site preparation, including weed control, ripping and mounding, should be done as for direct seeding. (If a tree-planter is used, it does the site preparation in the same operation as the planting, although it does not rip or mound as thoroughly.)

Planting should take place as soon as possible after the first rains to allow for the longest possible establishment time during the rainy season.

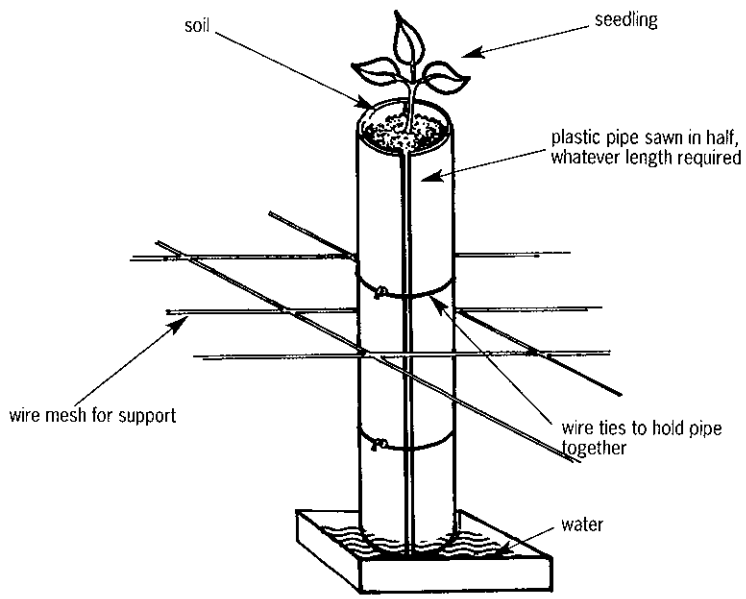
The preparation for planting seedlings within a remnant would also assist natural regeneration and be suitable for direct seeding.

Replanting Remnant Vegetation

In certain situations, planting seedlings can be a good option to assist in the rehabilitation of a remnant area. It is useful when:

- a quick result is desired
- control over the exact location of plants is required
- a rare or unusual plant which produces few seeds or has been raised from cuttings is being reintroduced into an area
- the tree layer is already established, and only small gaps need to be filled

Figure 10.2 A Caroll tube promotes deep root growth prior to planting into sandy soil



Regeneration by Fire

To set up a trial using fire in a previously-grazed woodland (see chapter 9 for more detail):

- **Fence the land to exclude subsequent grazing.**
- **Select a portion to be burnt.**

  As said many times in this publication, never apply an unpredictable technique such as fire to the whole of a remnant lest a disaster, such as a drought, wipes out all seedlings.
- **Ensure that the vegetation present carries viable seed.**

  Have additional seed available, if necessary, to spread onto ashbeds after the fire.
- **Ensure that there is fuel to carry a fire.**

  There should be some ground fuel to allow the fire to run, including some heaps to generate sufficient heat to crack the dormancy of any seeds stored in the soil. It may be necessary to leave the fenced remnant for several years to allow leaf litter to build up.
- **Consider creating heaps (chapter 9).**

  If building heaps, lay them as windrows across the contour to minimise any subsequent erosion. Heaps should not contain earth, as this downgrades the effect of the heap. Do not heap branches with viable seed as the fire will destroy that seed. Save these branches for brushing onto the ashbeds after the fire.
- **Consider the possibility of water erosion.**

  Heavy rain on a sloping site soon after the burn will cause erosion. Consider creating shallow mounds/banks to collect any seed. Do this prior to the burn.
- **Enquire about locusts.**

  If a locust plague is forecast, postpone the burn.
- **Control any perennial grass weeds present prior to the regeneration burn.**

  Some weeds, especially perennial grasses, grow extremely well after fires. Control them with herbicide before undertaking the regeneration burn. If there is only a small grass weed infestation, then seedlings can be eliminated with an overspray of selective herbicide after germination (see chapter 6).
- **Ensure that the vegetation present carries viable seed.**

  Have additional seed available if necessary to spread on ashbeds after fire.
- **Conduct the burn.**

  To mimic nature, it should be during autumn, and be hot. Although some plants will be killed, this should stimulate seed release from the standing vegetation, and germination of the soil seed-bank if there is any left.
- **Follow up with weed and rabbit control.**
- **Record what has been done.**

  Record what was done and pass on your knowledge to others.

- the remnant does not have sufficient plants left for natural regeneration or if a particular species has been lost due to grazing
- there is a difficult soil type for which special planting techniques can be used, for example mounding or Carroll tubes (see figure 10.2).
- there is a vegetation type that does not regenerate easily.

The Use of Fire to Stimulate Seed Release and Germination

Fire can be an important management tool to stimulate the release and germination of native plant seeds. The use of ashbeds has been discussed with regard to wandoo (see chapter 9), and ashbeds can be valuable for establishing other species, especially when combined with seeding or brushing.

Sometimes fire may be necessary to stimulate regeneration in previously-grazed woodlands in the agricultural area. Fencing alone will permit the regeneration of plants with large, long-lived seeds, such as jam, but often little else but weeds appear.

Revegetating Areas Adjacent to Remnants

Tree and shrub plantings may be combined with remnant vegetation to:

- extend vegetation over an area requiring soil conservation works, such as highly saline or erodible soils
- establish a commercial plantation, or woodlot for on-farm use (for example firewood, fencing timber)
- provide a buffer between the remnant and cleared land and thus:
  - trap wind-borne soil, fertiliser, herbicide and weed seed (see page 61)
  - filter ground water, absorb and use nutrients (see page 64)
  - protect the remnant from wind exposure
  - provide stock shelter, while protecting the remnant itself
- form a bush corridor linking remnants into a conservation mosaic (see page 177). These corridors may also function as windbreaks
- provide an extra source of food and shelter for wildlife, especially if nectar-producing shrubs are planted
- establish a seed orchard, perhaps as an integral part of a windbreak, shelterbelt or saltland revegetation planting. Plants with saleable seeds in these plantings can do the job they are designed for and provide some extra cash.

  Carefully managed plantations will produce more seed than bush-grown specimens. Species that need close observation at collection time (for example grevilleas) should be grown near the homestead or a frequently-used route for ease of access.

Water Harvesting

Tree survival can be assisted by planting seedlings within their own water-gaining earthworks (see diagrams). This has been done by the Israelis who have established orchards in the Negev desert without the use of irrigation water. But note that in heavy-textured soils plants should not be put into the base of furrows as they could become waterlogged and drown. Some tree-planting machines can be of limited value on these soils for that reason.[9]

Individual watering of seedlings should only be considered in remnant vegetation in exceptional circumstances - for example,

when trying to establish very difficult plants on very difficult sites. Even in these circumstances watering should only be considered for the first summer. It is simply too uneconomical in time and labour. Plants in remnants should grow on their own, or not at all. This is one reason why direct seeding is such a useful technique, as the plants establish and grow at their own pace. In addition, with no capital investment in seedlings, it is easier to bear a total failure caused by climate, locusts, or stock getting into the patch.

Fertiliser

It is usual in commercial tree-planting operations to add fertiliser to speed tree growth. It is inappropriate within remnant vegetation where the plants should grow at their own pace. Too much early leaf growth could lead to unnecessary stress during drought. In addition, fertilising promotes weed growth and it has been shown that extra soil nitrogen may increase the severity of insect defoliation of trees (see chapter 5).

Maintenance

Weed control should be maintained for the first couple of years, after which plants should have grown sufficiently to suppress weeds in their vicinity.

Rabbit control should also be on-going.

Connecting Remnants with Revegetation Corridors

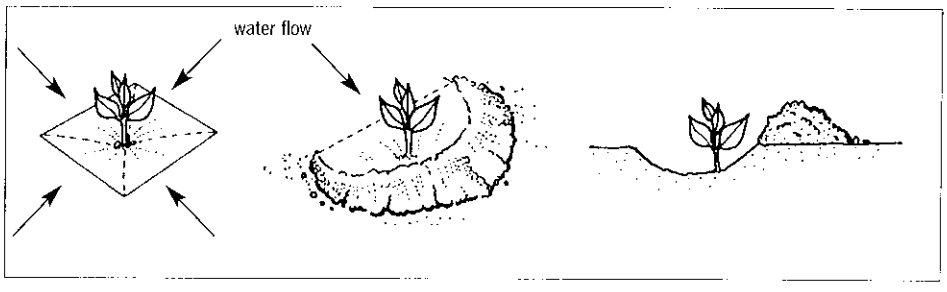
An important means of increasing the effective size, or carrying capacity, of remnants is to link them with other remnants.

Larger remnants, or ones which are linked into a mosaic, will usually support a greater diversity of animals; thus planning for native fauna must be done on a broader scale than just a single remnant, or even a single property. Neighbours can co-operate to provide bush corridors and shelter patches, linking the landscape into a conservation whole. People who adjoin conservation reserves such as national parks or nature reserves can help by managing land adjoining the reserve in a way sympathetic to conservation. Even small areas of land may contribute significantly to conservation values.

Most animals need resources from different places at different times of year (see chapter 7), and move to obtain them. In addition, young animals disperse away from their area of birth to establish new territories for themselves.

For a few animals, astonishing long-distance movement is necessary as they have evolved to find food, shelter or a mate in widely different areas - for example, a sharp-tailed sandpiper ringed at Pelican

Figure 10.3 Water harvesting around seedlings



Point in Perth was caught four months later in Siberia, a distance of 14 000 kms.[10] In contrast, Barbara York Main has shown that for some trapdoor spiders, young, dispersing females may only move a few metres beyond their mother's burrow before constructing their own burrow in which they will remain for the rest of their lives.[11]

In agricultural areas many animals will not cross open paddocks. A strategy to overcome this problem is to ensure that all remnants are interconnected by a system of bush corridors that unite all suitable areas into a habitat network. Even birds as large as Carnaby's cockatoo are better able to use patches of flowering shrubs if they can move to them along a bush corridor.[12] Even within the townsite of York, Bill and Jean Roy found that fairy-wrens would not cross the 150 m between their house and the river, where the wrens already lived, until the flowering shrubs and small trees that they planted as a corridor became large enough to provide food and shelter.

Again, corridors connecting remnants are a very effective means for expanding the effective size of individual pieces of remnant bush. Many animals - especially birds - have been seen using bush corridors, but there is little scientific evidence that details what sort of corridors are best for which animals. There is a general agreement, however, that wider is better and this is supported by CSIRO's work at Kellerberrin.[13] (See figure 10.4.)

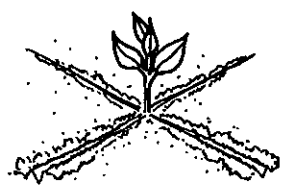
Another important feature is the structure of the corridor vegetation. The denser the vegetation, the more species will use it, as the work at Kellerberrin has also shown. There are far fewer bird species where trees only are present in the corridor, and this highlights the importance of a shrub layer to animal movement.

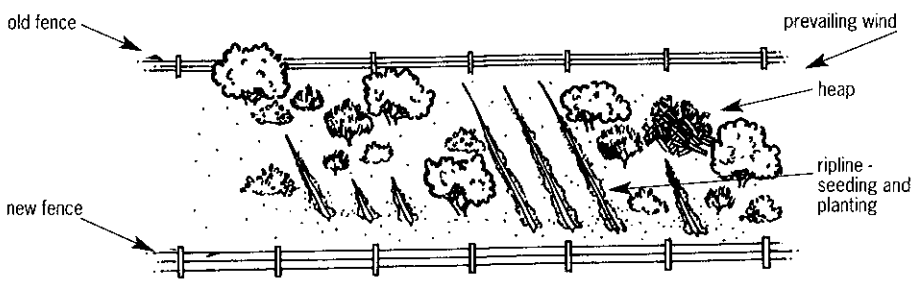
But note that corridors do not always

Rip lines and water harvesting

Alison and John Doley of Coorow have had good success on heavy clay loam by ripping in an X shape and planting at the junction of rip lines. Compared with planting along a single rip line, this configuration provides some water harvesting together with an all-round root development better able to cope with strong winds.

Within degraded remnant shelterbelts, the Doleys find that diagonal rip lines, at an angle to the prevailing wind and to the fence, and at the irregular distances apart caused by the need to avoid existing vegetation, will impart a more natural appearance to new plantings. Thus the appeal of an informal landscape is retained.

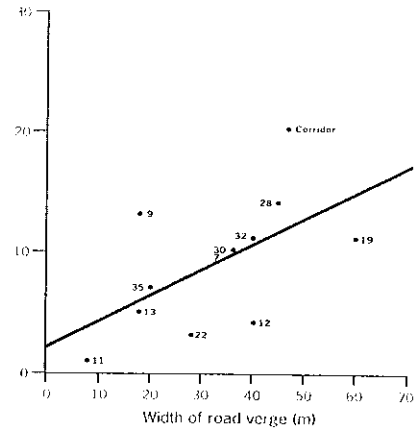




benefit desirable animals. Sometimes animals travelling along corridors are more susceptible to predation. If the corridors are very long, they may become a predators' picnic! However, the balance of current evidence strongly supports the use of corridors to connect remnant areas.

Corridors can be designed as windbreaks for stock shelter or erosion control - an excellent example of how nature conservation and production can be combined with mutual benefit, particularly if the animals occupying the windbreak play a part in controlling crop or pasture pests. There are good references that explain how to maximise benefits of windbreaks to production.[14] Revegetating existing remnants, especially restoring the understorey, can increase their value as windbreaks and remove any wind tunnelling effects.

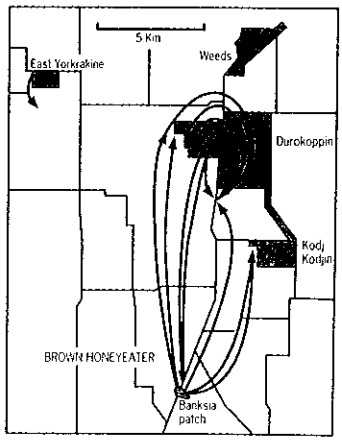
Figure 10.4 Relationship between number of bird species dependent on remnant vegetation in road verge sites and width of the verge



Brown honeyeaters and the banksia patch[15]

The few patches of banksia woodland left north of Kellerberrin are extremely important to various honeyeaters, which use them in large numbers when the plants are in flower.

Denis Saunders and Perry de Rebeira from CSIRO have banded birds and traced some of their movements. The diagram shows some of the journeys made by brown honeyeaters. The longest distance recorded for one of these tiny birds is 12.5 km. Since they have never been seen flying over open paddocks, they must have made the journey by following bush corridors along roadsides.



Not only is the banksia patch important for the survival of these honeyeaters, but so are the roadside bush corridors which enable them to reach it.

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Appendix - Some Management Plans

MANAGEMENT OF TOTAL HABITAT FOR NATURE CONSERVATION

Betty and Wally Shankland, Cadoux

Objectives

- To conserve bush for its heritage value for future generations.
- To use rain where it falls.
- To ensure the survival of malleefowl in the area.

Relevant Information

Land available: Two ungrazed patches of remnant vegetation totalling 600 acres plus 200 acres grazed, consisting of scrub and exposed rock outcrop. (Decision to preserve these for heritage made when the farm was first cleared in the 1930s.)

Fire regime: Occasional fires occurred, associated with clearing in the district, up until the 1940s. No fires since. Consider that a natural fire interval in this area is probably 30-50 years.

Introduced animals: Foxes, cats and rabbits occur.

Plan of Action

- No grazing by stock in area that has never been grazed.
- Control feral animals: rabbits controlled at first appearance; foxes controlled (in the last 20 years, 2 300 foxes killed); cats treed by dogs, then shot.

Results, Monitored 1990

- Breeding population of malleefowl remains - four active nests.
- Euros exterminated, believed killed by shooters on neighbouring properties.
- Bush healthy, but even-aged. No weed infestation.

Future Actions

- Continue as above.
- Design and carry out a regeneration burn in a section of bush, with the aim of creating a mosaic by having a number of such burns in subsequent years. Burns need to be carefully designed and carried out to minimise disturbance. Need an intense burn to crack seed dormancy; late autumn best.

MANAGEMENT TO CREATE A BUSH CORRIDOR

Men of the Trees[1]

Objective

To help conserve the numbat by linking Colac South Block to the main Dryandra Forest by a bush corridor along Colac Road and so provide numbats with better access to a greater area of habitat.

Relevant Information

- numbats occurred in the main block of Dryandra Forest but not in Colac South block
- the two areas are separated by 600 m of cleared farmland and linked by Colac Road

- numbats will not move far from refuge sites (hollow logs and dense vegetation)
- the paddock on one side of the road is owned by Rodney Dowsett, on the other by John Young
- Men of the Trees has a nursery that could grow trees, and a network of volunteers who could plant them.

Plan of Action

- approach the landowners to see if they would agree to tree-planting in a 50 m strip parallel to the road. (They agreed, provided a good fence was installed - 1987)
- organise weed control, deep ripping, fence materials, 4 000 seedlings of local trees, sundry machinery and 60 volunteers (1987-1988)
- organise some funding from Greening Australia (1988)
- erect the fence and plant the trees (1988).

Results, Monitored 1991

- seedling survival - in excess of 90 per cent
- seedling growth rate - wandoo now two metres, flooded gum three metres, self-sown rock sheoak two and a half metres, and jam two metres
- animal use: grey kangaroo, echidna and numerous small birds observed using the corridor

  and
- numbats have been recorded in Colac South block! (But it is not known whether they actually used this corridor.)

Future Action

- add hollow logs between the trees as a further incentive for numbats and other small animals to use it (1992-3).

MANAGEMENT FOR WILDFLOWER HARVESTING

Managing showy dryandra for cut flowers.

Joe and Beatrice Watson, Bolgart

Objective

To obtain some income from a sustainable harvest of showy dryandra flowers.

Relevant Information

Vegetation community: This wandoo forest remnant contains a diverse understorey including showy dryandra (*Dryandra polycephala*). It was already fenced and had never been grazed.

Life cycle: Upright shrub, grows from seed after disturbance (usually fire), begins flowering at three to four years old, pickable at about seven years, tends to die at about 15 years. Susceptible to *Phytophthora* dieback.

Quality requirements for commercial sale of showy dryandra:

- new wood only
- long (over 50 cm) straight stems only - the longer, the more valuable
- no seed cones allowed.

Observations Made during Picking

Picking commenced in 1980. It was noted that

- many stands were too dense for easy access and produced poor stems
- regrowth after cutting produced excellent stems.

Plan of Action

- increase production of saleable stems by trialling several methods
- protect from *Phytophthora*
- protect from wildfire.

Methods and Results

Method (1):

Rolling of older thickets to encourage new upright growth and new seedlings (in March - dry soil conditions, less risk of *Phytophthora* - rains follow, gives plants a good start)

Results:

- saleable stems produced in the second year
- thickets still too dense for easy operation.

Method (2):

Burning, autumn 1989, at night after first rains for moderate fire plus safety.

Results:

- excellent germination, including a wide variety of other very attractive wildflowers
- some pickable stems expected by 1993.

Method (3):

Pruning with hedge-clippers soon after saleable stems have been cut (September).

Results:

- excellent crop of very saleable stems produced in the next season
- bushes have been pruned in this way for three years without diminishing the vigour of the new growth.

This has proved by far the most successful method.

Method (4):

Heaping, burning and rough plough in.

Results:

- trialled spring 1991. No results as yet.

Future Actions

- continue with fire and disease protection
- use a combination of burning sections and pruning to produce a sustained supply of flowering stems in future years.

MANAGEMENT OF A WEED

Management Plan for the control of bridle creeper.

Department of Environment and Conservation (DEC).

Objective

To control bridle creeper infestations in nature reserves in DEC's Katanning District.

Relevant Information:

- bridle creeper is a herbaceous perennial with climbing stems growing annually from a dense mat of perennial root tubers. It was introduced from South Africa as a garden ornamental
- seeds, enclosed in red, fleshy fruits, are dispersed by birds
- Tubers can be mechanically spread by machinery
- highly invasive of bushland, particularly moist, disturbed areas and along water-courses
- dense growth habit competes aggressively for light and nutrients, inhibiting the growth of native plants
- manual removal and contact herbicides are both effective.

Plan of action:

- plot all infestations on maps of the reserves
- target small, isolated infestations first
- attack large infestations around perimeter, working towards centre
- dig up small, isolated plants, taking care to remove all tubers
- spot spray larger plants with glyphosate (1 part to 50) just prior to flowering when plants are at maximum size - August to September, depending on locality

- use a rake to pull plants away from their shrub support and spray when flat. This minimises damage to native shrubs
- repeat spraying annually until control achieved - anticipate three years minimum
- continue monitoring treated areas for re-infestation.

Results:

- work commenced in 1989
- small infestations eradicated from two reserves
- control of moderate infestations on two reserves should be achieved by 1993
- containment of severe infestations on two reserves on-going.

MANAGEMENT OF THE MALLEEFOWL *Leipoa ocellata*

Relevant Information

Habitat requirements: An area of at least 100 ha of ungrazed woodland, sandplain, scrub or mallee. A dense, shrubby understorey and litter layer is essential. Grazing by stock removes the litter layer, essential for mound building, opens the shrub canopy, increases predation and consumes seeds which the birds eat.

Fire management: A mosaic of vegetation in different ages and stages of shrub growth is probably best.

Studies in the Victorian mallee have shown that broadscale fire eliminates malleefowl in the short term, although they can survive and breed in unburnt patches of vegetation. It was also found that 20 to 30 years after a fire, breeding densities had only reached about one third of those in long-unburnt bush. Therefore it was concluded that fire frequency in excess of 60 years is required to optimise breeding conditions for mallee fowl.[3]

Food: Malleefowl eat seeds, principally wattles and peas, flower buds and some insects. In the wheatbelt they are known to eat wheat.

Breeding: Malleefowl mate for life. The male digs a hole one metre deep and three to four metres wide then rakes in leaves and twigs from a radius of 25 m to form a mound. The female lays up to 33 eggs in the centre of the mound where the heat from the decaying vegetation incubates them. The male maintains the temperature around the eggs at exactly 33°C by adding or removing the covering layers of soil and twigs.

Predators: Foxes take large numbers of young.

Availability of animals: If suitable habitat is adjacent to existing populations, animals will probably disperse into it, especially if foxes are controlled.

MANAGEMENT OF THE LONG-NECKED TORTOISE *Chelodina oblonga*

Relevant information

Habitat requirement: permanent fresh or slightly brackish rivers and swamps, including farm dams. Long-necked tortoises require good quality fresh water to survive and reproduce over long periods.

In estuarine conditions they seem to be able to survive as adults for two or three months, then move out of estuaries into fresh water with winter rainfall. They probably can't feed in very brackish water, and eventually they need access to fresh, or near fresh, water for food and to flush any build up of salts from their bodies. If they have access to fresh water seeps or drains, this may allow them to persist for longer periods in brackish water.

Well-vegetated banks are valuable. Tortoises leave the water to lay eggs in a hole, sometimes some distance from the swamp, and can travel overland between swamps.

Food: Long-necked tortoises will eat a wide range of foods, including plants, carrion and water animals such as insects, crustaceans, tadpoles and small fish. They will also take baby waterbirds.

Predators: Young are taken by water rats and snakes. However, foxes are a major predator. A DEC officer recently found a fox den near the Hotham River with six to eight tortoise shells scattered nearby. This seems a high level of predation. If tortoises are moving between pools during summer, they are likely to be particularly vulnerable to foxes. Therefore fox control may be required (see chapter 8).

Hydrological factors: A major threat to tortoises, particularly in the eastern part of their range, is increasing salinity of wetlands. Once the salinity reaches a high enough level, reproduction will cease, but adults can survive. At this point the system has gone too far and the tortoises will eventually disappear although the adults may persist for quite some time. Prolonged exposure to very brackish or very saline water will kill all the tortoises.

Management Actions:

Protect tortoise habitat from rising groundwater. Revegetation around pools used by tortoises should achieve this.

Maintain or improve the health of the total catchment upstream of tortoise populations. Revegetation of the drainage line in which tortoises are living will help; some consideration will need to be given to reducing recharge of the catchment.

Minimise the surface and groundwater flushing of fertilisers into wetlands. There is evidence that algal and bacterial "blooms" are increasing in wheatbelt wetlands. If concentrations of phosphate and nitrogen increase in dams or other wetlands, then the frequency of massive growths of algae and bacteria will also increase and tortoises may die from infection. This process of eutrophication can lead to other problems, including botulism.

Provide a freshwater refuge nearby. If there is a dam nearby it may be worth watching to see if tortoises use it. If they do, then improve this as a tortoise habitat. It will also help if the dam has a diverse array of aquatic plants and animals, or some other food source is available. For aquatic plants you would require reasonably clear water, but tortoises themselves can tolerate muddy water.

In summary, the actions which are required to better protect catchments and farmland from hydrological changes are likely to favour the protection of tortoises. As is often the case, the management actions required for sustainable production and conservation are closely linked.

Availability of animals: Long-necked tortoises will often reach suitable habitats if they are not too isolated from existing populations.

Index of Species

Lists of birds can be found on pages 40 and 43, and of frogs on page 44.

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