THE EXTRAORDINARY NATURE OF

The Great Western Woodlands

By Alexander Watson, Simon Judd, James Watson, Anya Lam, and David Mackenzie

THE WILDERNESS SOCIETY

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The Great Western Woodlands - Visual Imagery
An icon using Eucalyptus leaves has been developed and adopted for this publication. There are 351 species of *Eucalyptus* found within the Great Western Woodlands. Colours used throughout the report have been chosen to reflect the varied appearance of the leaves during their lifecycle and the wide spectrum of colour that exists between species. Its decay also reflects the enormous difference between the Western Australian Wheatbelt and GWW.

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Acknowledgements

Sunset overlooking Lake Johnstone. Barbara Madden

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Foreword

My first encounter with the Great Western Woodlands was as a teenager in 1965, immigrating to Perth from eastern Australia. Beyond Balladonia, travelling west out of the Nullarbor, an extraordinary woodland unfolded, as rich in eucalypt trees and mallees as some tropical rainforests are in trees of any kind. I had little notion of, or interest in, this arborescent diversity at the time, but was struck by the handsome colourful bark of some of the eucalypts. Over the past three decades, countless trips throughout these woodlands in collaboration with CSIRO eucalypt specialist Ian Brooker led to us describing more than 35 species of eucalypts as new to science. Our colleagues the late Lawrie Johnson, Director of the Royal Botanic Gardens Sydney and botanist Ken Hill described an additional 25 species from the Great Western Woodlands, and new species continue to be discovered as collection intensifies. This is pure heaven for those smitten by trees of arid country.

Many other groups of plants are similarly replete with undescribed species in the Great Western Woodlands. It's a botanical mecca. Here painter Philippa Nikulinsky was born and raised, affording extraordinary opportunities to hone her skills in botanical exploration and artistic discovery. Here many others arrive from afar, enticed by floral wealth and sheer wonderment.

In June 1979, I was first able to visit the heart of the Great Western Woodlands as a professional biologist, employed by the Department of Fisheries and Wildlife. Joining me were recently appointed management planner Ian Crook and his gifted writer/artist wife Gillian, fresh out from New Zealand and keen to experience the Western Australian outback. We drove east on Great Eastern Highway from Perth 600 km to search for rare eucalypts on two granite outcrops famous as campsites on the goldfields south of Coolgardie — Gnarlbine Rock and Queen Victoria Rock. The amiable local Kalgoorlie Wildlife Officer at the time, Leon Sylvester, joined us for a memorable camp overnight beneath a cold winter's sky bedecked with myriad stars. We woke to an almost deafening dawn chorus of Brown Honeyeaters and Red Wattlebirds, with a few small flocks of Purple-crowned Lorikeets skitting rapidly past above the canopies, and the unusual grating warble of Spiny-cheeked Honeyeaters adding additional aural spice to the cacophony.

Walking around and over the subdued ancient eminence of Queen Victoria Rock, I encountered many of the classic plants of the Great Western Woodlands. Salmon gums loomed 20 metres high above all else, remarkably tall for a region experiencing a desert rainfall regime. Rock oaks (*Allocasuarina huegeliana*) flanked the massive granite in groves through which the wind sighed. There were numerous wattles, sandalwood and quondong, mistletoes, spinifex, native pine, chenopods, pigface and daisies. On the granite in cracks and fissures were many plants that had caught the eye of Spencer Le Marchant Moore, the Kew botanist first to explore these woodlands in the 1890 s — rock isotome (*Isotoma petraea*), distinctive pincushion 'lilies' (*Borya constricta*) lining the shallow soils adjacent bare rock, greenhood and donkey orchids, and myrtaceous shrubs such as *Melaleuca elliptica* and *Kunzea pulchella*, gnarled and stocky, both resplendent at other times of the year in red brushes of flowers full of nectar for the honeyeaters.

On flatter surfaces of the ageless rock were the shallow pools of freshwater known as gnammas. In the mud beneath their clear waters lived tiny annuals of the snapdragon family, appropriately called mudmuts (*Glossostigma diandrum*), about which swam a busy diversity of aquatic invertebrates and tadpoles. Adjacent the pools in damp soil were numerous other annual herbs of great richness in colour and shape when inspected closely. Resurrection ferns (*Cheilanthes*) sat nestled among boulders or ledges. Sundews (*Drosera peltata*) formed elegant glistening miniature forests, their sticky red leaves entrapping insects for a slow death through enzymatic absorption. This was mesmerizing richness, with the added pleasure of freshwater present in an otherwise dry landscape.

In a warming world where ongoing destruction of wild vegetation accounts for a fifth of global carbon emissions, more than all transport systems combined, we need to rethink the value of these inspiring woodlands. Nowhere else on earth can be found such extensive areas of eucalypts. They quietly absorb carbon for us, retain unexplored biodiversity, sing the songlines of Aboriginal people, and have a brief European history of interest in its own right.

If ever there was a time for a global moratorium on further destruction of wild vegetation, now is it. We must care for what remains, repair and restore its fabric where damaged, and extend its cover where possible, if for nothing else but the selfish reason of wanting to mitigate the worst aspects of looming global warming. We would all be immeasurably diminished if future travellers were unable to enjoy the spirit of such magnificent woodlands and country. This report is an eloquent call for conservation of the Great Western Woodlands. My hope is that the message is heard.

Professor Stephen D. Hopper FLS
Director, Royal Botanic Gardens, Kew

Summary

This study has been undertaken to inform all those individuals, communities and organisations with an interest in the Great Western Woodlands. The authors hope the report will act as a catalyst to bring people together to discuss the central challenges that must be met if the nature of the region is to be conserved. Stakeholders include residents of local communities, Traditional Owners, local shire councils, the Western Australian and Federal Governments, mining and tourism companies, four-wheel drive clubs, apiarists, wildlife enthusiasts, conservation organisations and scientists. It is time to look more closely at the future of the Great Western Woodlands, and to develop a comprehensive plan to protect it.

The 'Extraordinary Nature of the Great Western Woodlands' introduces one of Earth's most ecologically significant regions. In the south-west of Australia, east of the Rabbit-Proof Fence, lies the Great Western Woodlands—one of the world's last wild places.

The Great Western Woodlands contains the largest and healthiest temperate woodland remaining on Earth. The region covers almost 16 million hectares, 160,000 square kilometres, from the southern edge of the Western Australian Wheatbelt to the pastoral lands of the mulga country in the north, the inland deserts to the northeast, and the treeless Nullarbor Plain to the east. This is a vast area, nearly three times as large as Tasmania.

Landscapes with similar climates and geography in South America, North America, Africa and Europe have all experienced a heavy human footprint. Almost all of their original vegetation has been replaced with agriculture and urban sprawl, and the remnants heavily logged for timber and firewood or overgrazed by cattle, sheep and goats. Similar ecosystems in other areas of south-western and eastern Australia have also been cleared for agriculture. In contrast, the Great Western Woodlands remains relatively unspoilt, making the region of both national and international significance.

This huge area of eucalypt woodlands, open bushland with scattered trees, is intermixed with thicker eucalypt mallee, low shrublands, and grasslands. The exceptional plant diversity within these vegetation types, with over 3000 species being recorded to date, is one of the primary reasons for the region's conservation significance and why the entire region should be considered a biodiversity hotspot. Across the landscape, these species change rapidly, many occurring only in localised areas. This creates a mosaic of ecological communities throughout the region.

The Woodlands' diversity has evolved in a landscape with an unbroken biological lineage stretching back some 250 million years. Having not experienced mountain building, glacial events, or ocean submergence since that time, these lands have a uniquely continuous biological heritage that includes the development of the first flowering plants, the coming and going of dinosaurs, and the appearance of humans. The interplay between the age of the lands, the complexity of the soils, the climate, and isolation from eastern Australia, have all combined to allow the Woodlands' exceptional diversity of species to evolve.

Recent Australian research has highlighted the importance of 'ecological processes' in maintaining these populations of plants and animals, as well as the health of the broader ecosystems in which we all live. As the key interactions and connections between living and non-living systems, these processes include movements of energy, nutrients and species. Hydro-ecology, for example, is the connection of water and wildlife in a landscape. Other important ecological processes include fire, plant productivity, and 'keystone' plants and animals whose presence maintains many other species. Unlike most of southern Australia, these ecological processes remain largely intact in the Great Western Woodlands. Their protection and maintenance is essential to maintaining healthy populations of species, ecosystems, and the human communities they support.

One of these major processes, climate change, illustrates the importance of the region on a national and global scale. The Great Western Woodlands has massive carbon stores in its biomass, woody debris and soil. Poor land management can release this carbon as greenhouse gas pollution, such as that released when bushland burns. Proper protection and management of the Woodlands will therefore assist in reducing Australia's greenhouse gas pollution.

Reflecting on Woodlands. Barbara Madden

Historically, land management in the Great Western Woodlands was done holistically by the Indigenous people who lived throughout the region into the 19th century. That changed, however, with the influx of miners, pastoralists, woodcutters and farmers in the late 1800s. Since that time, the pattern has been for both Indigenous and non-Indigenous people to become concentrated in population centres. There are approximately 40 000 people currently living in the shires that include the Great Western Woodlands, with the great majority of these residing in towns.

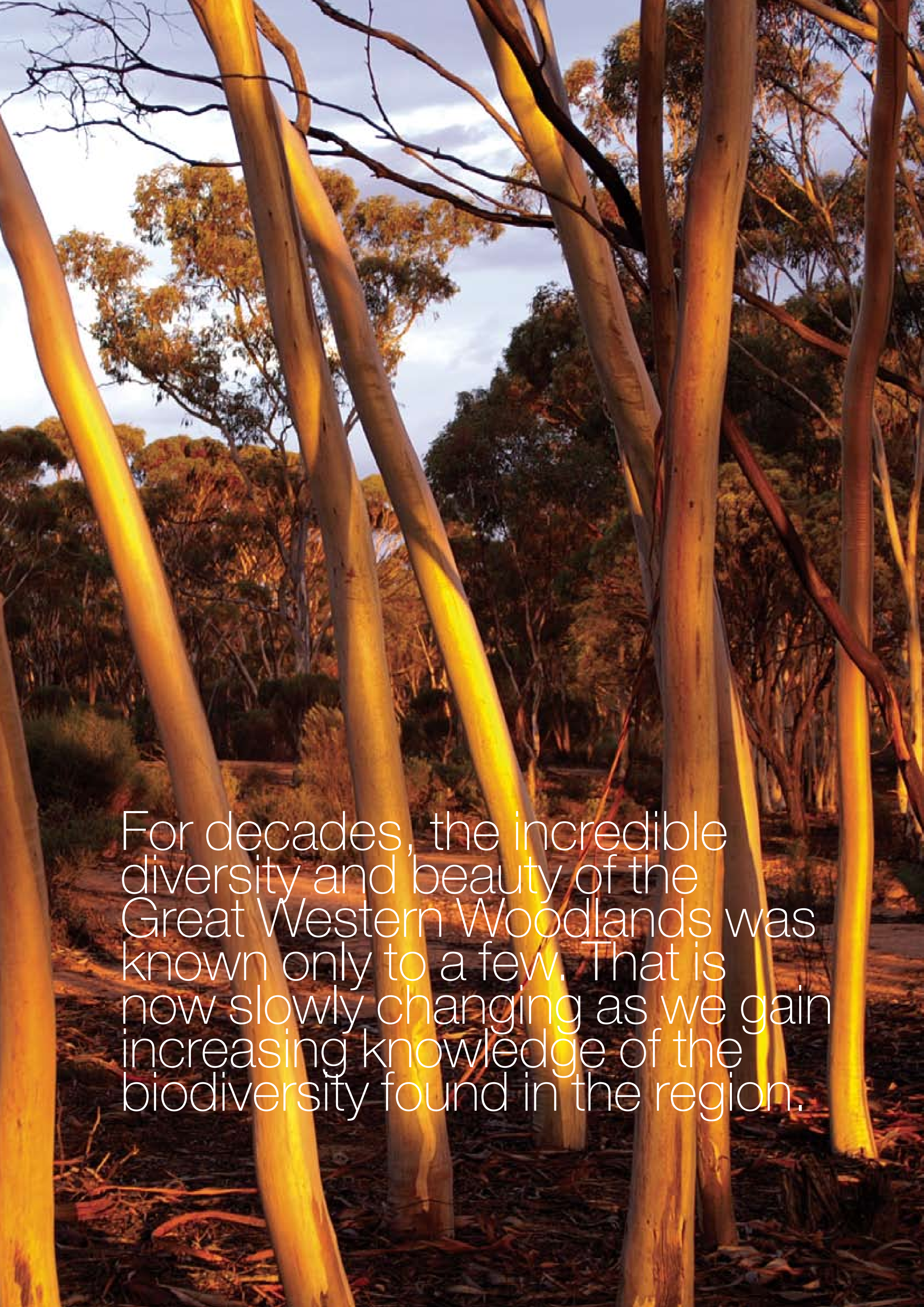
Effective planning for the future of the region will require addressing the currently fragmented approach to its land management. With so few people living on-country and actively managing the landscape, one of the key questions we need to answer is how we can best maintain the natural values of this place with so few active custodians.

Active management is needed to deal with the current threats to the native plants and animals of the Great Western Woodlands and the ecological processes that maintain them. These threats include inappropriate fire regimes, with huge uncontrolled fires now occurring regularly; introduced animals and plants; and habitat removal caused by resource extraction activities such as mining and logging. These threats are currently managed independently of one another, without consideration of the broader landscape issues, such as maintaining ecological processes, or the cumulative damage done by individual smaller activities occurring in different parts of the region. Similarly, broader land management policies reflect an array of different, and sometimes conflicting management practices that occur across different land tenures, including Unallocated Crown Land, pastoral lease, conservation reserve, and a small proportion of freehold land.

We therefore propose that a new model for land management be developed for the Great Western Woodlands; one that maintains and protects the Woodland's natural values such as threatened plants and animals and the supporting ecological processes, and one that includes all land—across all tenures—and involves all stakeholders in the region.

This is the challenge, now and in the coming decades. Without recognition and protection through a strong and rigorous conservation plan, the amazing diversity of life found in the Great Western Woodlands will continue to be at increasing risk.

If we act now we have the opportunity to secure the protection and long tern survival of one of the world's last great wild places. The choice is in our hands.



For decades, the incredible diversity and beauty of the Great Western Woodlands was known only to a few. That is now slowly changing as we gain increasing knowledge of the biodiversity found in the region.

01 | Introduction

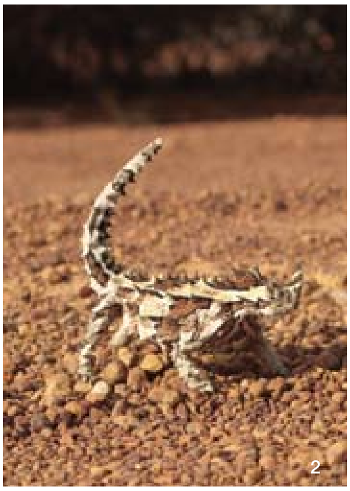
If you were to head east from Perth, over the escarpment hills of the Darling Range and through the forests dominated by jarrah, marri and wandoo, you would eventually enter the great sweep of cleared country known as the Western Australian Wheatbelt. Here, small towns emerge from a rolling landscape dominated by wheat and pastures, and punctuated by occasional small patches of trees and bush spared the axe by early pioneers. Driving further east, a dark green line appears on the horizon, first blurred, then sharper. Here a simple fence marks a line between the Wheatbelt and the beginning of a remarkable place—the Great Western Woodlands.

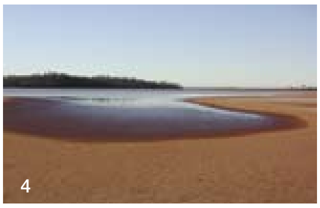
Looking east from the fence—the famous Rabbit Proof Fence—lie tens of thousands of square kilometres of bush. This rich tapestry of woodlands, mallees and shrublands connects Australia's south-west corner to its inland deserts. It is a land of granite rock islands, of shrubby plains, of mallee and red dirt, and of woodlands that are so vast that ancient hydrological patterns still operate and clouds still gather in response to the vegetation beneath. Nowhere else do large trees of such variety grow where water is so scarce and the soil so depleted of nutrients.

In modern Australia this is of great significance. The Great Western Woodlands is one of the very few large, intact landscapes remaining in temperate Australia. Globally, too, as a large region with abundant natural diversity, it represents an increasingly rare landscape. The southern portion of the Woodlands is part of the south-western Australia biodiversity hotspot, one of only 34 such hotspots recognised scientifically[1], and there can be little doubt that, once more comprehensive survey work is completed, the whole Woodlands will be included in this listing.

The Great Western Woodlands has played an important role in Australia's human history as well. This is the land of several Aboriginal nations, and traditional ties to the land remain. It is also the outback that met the eyes of thousands of 19th-century gold prospectors who came to seek their fortunes in the goldfields surrounding Kalgoorlie.

Opposite Page Image. Barbara Madden
Below. The Rabbit Proof Fence east of Hyden. Alexander Watson





For decades, the incredible diversity and beauty of the Great Western Woodlands was known only to a few. That is now slowly changing as we gain increasing knowledge of the biodiversity and importance of the region. With this knowledge, however, has come the understanding that, despite its size, the Great Western Woodlands is at risk, from changing fire patterns, from weeds, from feral animals, and from the risks posed by increased pressure for minerals and other resources. We must act now if we want to preserve this unique region for future generations.

Aims of This Report

When the Wilderness Society first began working in the Great Western Woodlands, it became quickly apparent that the area was of outstanding conservation significance. However, most knowledge on the region is scattered in inaccessible technical reports. This document attempts to remedy that situation by bringing together our existing knowledge on the region in one accessible format, as well as analysing needs for further study and improved management.

We have written this study for all those who value the Great Western Woodlands and its future. It is a preliminary analysis based on readily available data. In it, we detail current knowledge of the biological diversity and conservation significance of the region, as well as our current understanding of the ecological processes that sustain its variety of life. Finally, we outline a framework for future management, to ensure that the exceptional nature of the country is maintained.

The Region

The Great Western Woodlands is a huge expanse of natural bush in south-western Australia (Fig. 1.1). At almost 16 million hectares, it is more than twice the size of Tasmania and larger than England. Despite being biologically distinct, the region has never had a unique name, usually simply being referred to as part of the 'Goldfields' region. The name 'Great Western Woodlands' was selected because it best reflects the region's position in the west of the continent and status as containing the largest remaining area of temperate woodland in Australia.

The boundaries of this distinct bioregion were established by researchers from the Australian National University. The boundaries separate the eucalypt woodlands from the mulga (*Acacia aneura*) country to the north, the treeless Nullarbor Plain to the east, the moist coastal heath to the south-east, and agricultural land to the west and south. This boundary was drawn using satellite data that identified a characteristic 'eucalypt' spectral signature[2] that is found throughout the Great Western Woodlands.

1. Salmon Gum Woodland. Chris Dean
2. Thorny Devil (*Moloch horridus*). Barbara Madden
3. Spectacular wildflowers are found throughout the region. Charles Roche
4. Lake Johnstone. Alexander Watson
5. Overlooking the woodlands from Burra Rock. Barbara Madden

This signature reveals that, unlike other bushland areas of southern Western Australia, the region is dominated by eucalypt woodlands (ecosystems resembling forests but with a more open canopy [3,4]) (Box 1.1) although it does also contain many other ecosystems, including mallee, shrublands and grasslands.

The landscape that is now known as the Great Western Woodlands is delineated in part because of agricultural practices over the last 150 years. At the western edge of the Great Western Woodlands, on the other side of the Rabbit-Proof Fence, is a landscape where our human footprint has been heavy. Here, over 18 million hectares (44 million acres) of bush (woodland, mallee and shrubland) were cleared in less than a century[5]. This area has lost its original identity and is now known as the Wheatbelt, a homogenized landscape that supports predominantly agricultural production including sheep, wheat, barley and canola[6,7]. The human-produced boundary between these two starkly different landscapes is clearly visible from space (Fig. 1.1; Box 1.2).

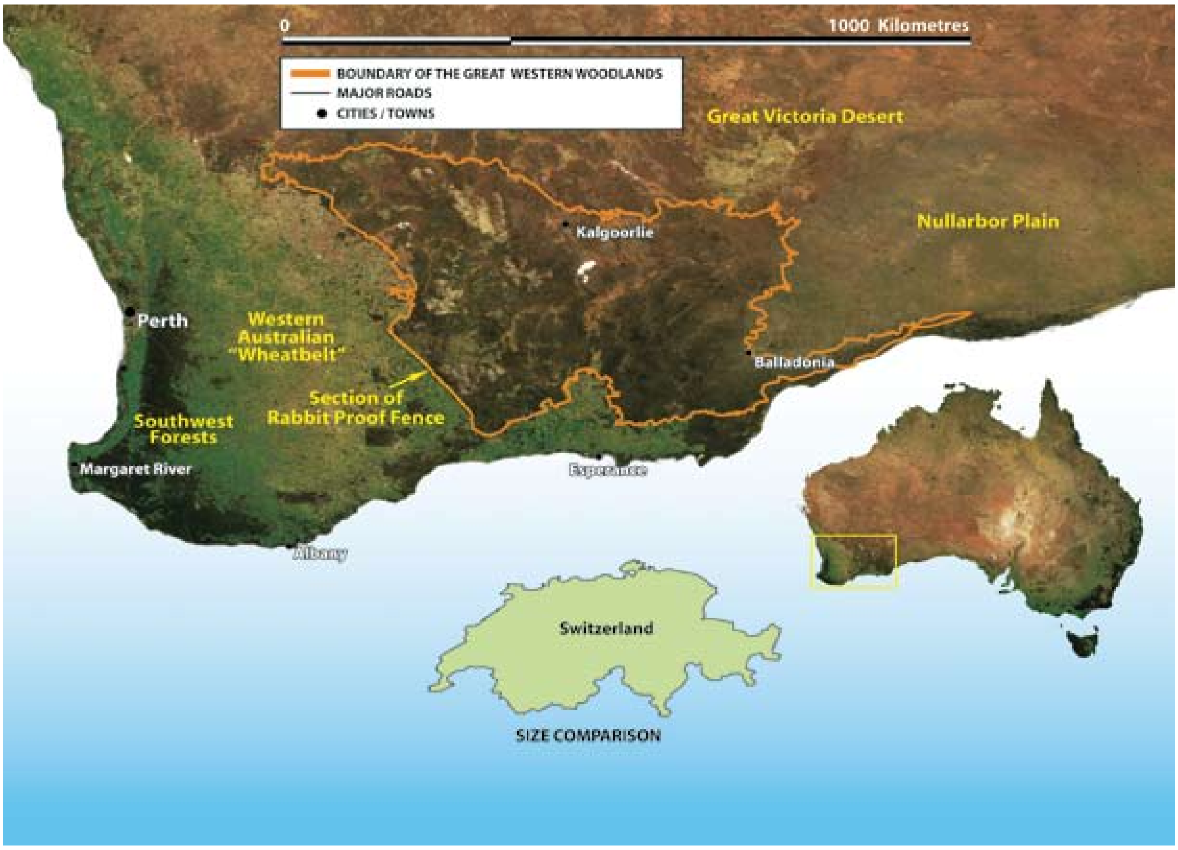


Figure 1.1
Map of southern Western Australia showing the boundary of the Great Western Woodlands.
A map of Switzerland is also shown to illustrate the relative size of the region.

Box 1.1 - What is a woodland?

Dr Barry Traill

Say the word 'woodlands' to Australians, and they are most likely to picture the dense green woods of the English countryside. Botanically, however, woodland is defined as treed areas with sparser trees and more open canopies than denser forests such as the jarrah and karri forests of the far south-west of Western Australia. Woodlands are also usually lower in height than forests. The understorey of woodlands varies with the soils; some have dense shrubbier understoreys, while others are open and grassy. In Australia, there are 'temperate woodlands' in the south, and tropical woodlands, also called tropical savannas, in the north. While the tropical woodlands remain largely intact, approximately 85% of all temperate woodlands have been cleared for agriculture.

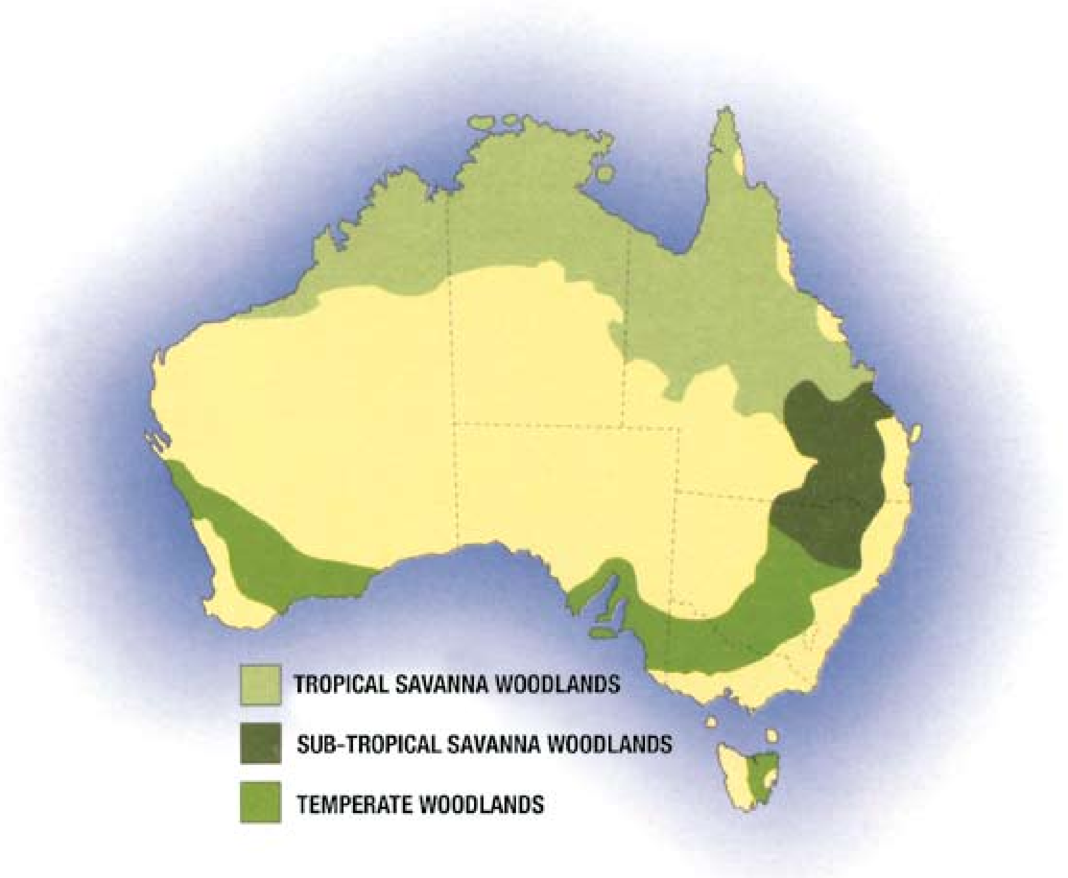


Figure 1.2
The distribution of tropical, sub-tropical and temperate woodlands in Australia, before European colonisation (modified from Australian Conservation Foundation 2000)[8].

Some of the healthiest woodlands left in Australia. Barbara Madden

Box 1.2 - Drawing a line in the sand

Keith Bradby

How did a large piece of seemingly plough-able land survive until now? The short answer is 'only just'. The longer answer involves a mixture of lucky escapes and determined individuals.

Western Australian agriculture began it's main inland spread, away from the west coast, in the early 1900s. In the early decades, with plenty of land at their disposal, farmers and officials concentrated on the more fertile woodland soils, largely leaving alone the soils found underneath the adjacent shrublands or mallees. By the time the Great Depression hit, isolated farms had spread almost as far east as the Rabbit Proof Fence. One result was that in 1930 there arose a concerted attempt to allocate large sections of the Great Western Woodlands for farming. The plan was shelved, however, when the soil scientist sent out to survey the area presented strong evidence against the agricultural viability of large portions of it [9,10].

Expansion therefore remained slow through the Great Depression and Second World War, but accelerated after the war when science, the availability of heavy machinery, high commodity prices, and even the weather made agricultural expansion favourable. For 20 years over 'a million acres a year' was allocated to farming, with bulldozers sweeping across the less fertile areas bypassed earlier. Large blocks of new farms were allocated up to the edge of the Rabbit Proof Fence, while east of the Fence the government established crop trial sites and prepared to allocate more large areas.

In 1969, dry seasons returned and world wheat prices crashed. As a consequence, land allocation ceased, and across the south-west many newly selected blocks were abandoned. But by the late 1970s production and prices had improved slightly, and in 1979, the Western Australian Government announced its intention of sweeping the Rabbit-Proof Fence aside and pushing farms through in a belt across the southern Woodlands (Fig. 1.3).

Fortunately, in the early 1980s, an emerging landcare ethic was jostling with the 'rip, tear and bust' approach of earlier decades [11]. A change in government in February 1983 saw a moratorium on any further land allocations,[9] which was later extended indefinitely.

And that is the very tenuous basis by which the Rabbit-Proof Fence continues to delineate the stark contrast between the battered landscapes of the Western Australian Wheatbelt and the remarkable richness and beauty now being discovered to the east.

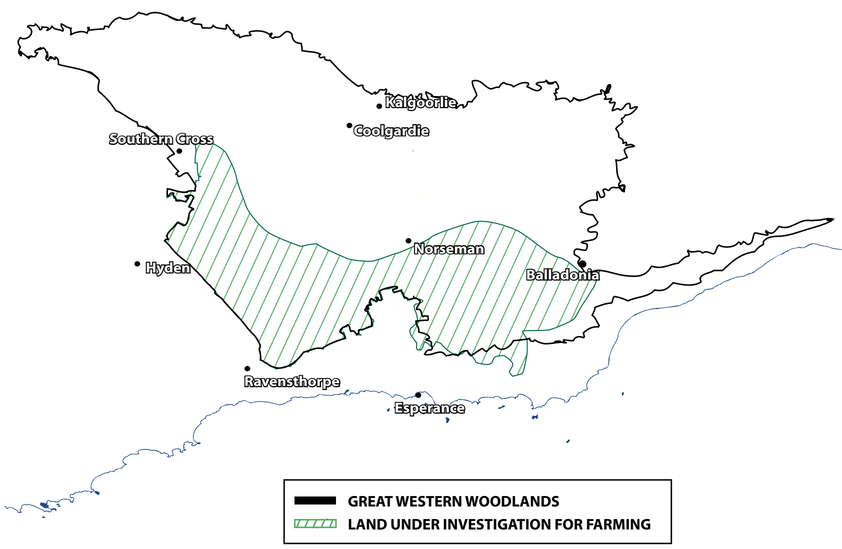


Figure 1.3

The 1979 proposal[12] for farming land in the Great Western Woodlands

1. Ecological Apartheid.
2. Early farming. Battye Library (029205PD)
3. Roller machine used for thickets. Battye Library (003198D)

Emu tracking across a salt lake. Barbara Madden

Indigenous ecological knowledge

This report reflects the perspective of western-trained conservation scientists. It does not present an Indigenous perspective or Indigenous ecological knowledge of the Great Western Woodlands. As such, we acknowledge that this report—in terms of an account of the land's natural and cultural values—is incomplete.

Indigenous laws and customary practices have shaped the environments of Australia for thousands of generations, and the colonial dispossession and dislocation of the Traditional Owners has contributed to the ecological problems now facing some parts of the Great Western Woodlands.

Indigenous ecological knowledge, both traditional and contemporary, has an essential role in considering the future of Australia's biodiversity and associated natural values. Our hope is that this report will not only present a timely account of the Great Western Woodlands' natural values and recommendations in the face of urgent threats, but will also be received as a contribution to dialogue with Indigenous knowledge holders and Traditional Owners.

The structure of the study

In this study we begin by describing the diversity and significance of the Great Western Woodlands, and finish with a discussion of the on-ground management requirements of the region. The specific chapters are as follows:

- Chapter 2 outlines our knowledge to date about the regional, national and international significance of the Great Western Woodlands' 'biodiversity' by focusing on plant and vertebrate communities in the region (see Box 1.3 for definition of biodiversity).
- Chapter 3 describes how the landscape evolved and how this provided the platform for the evolution of the rich variety of life that now exists.
- Chapter 4 describes some important ecological processes that need to be understood and preserved in order to protect the biodiversity and natural heritage of the region.
- Chapter 5 introduces the people who have lived or are currently living in the Great Western Woodlands, providing a social, political, cultural and administrative context for the region.
- Chapter 6 outlines the need for the entire landscape to be managed across tenures and by multiple stakeholders over the long term.

Box 1.3 - Biodiversity

Professor Michael Soulé

The catchword 'biodiversity' has become a rallying cry for the latest generation of scientists and environmentalists involved in conservation issues. At the Earth Summit in Rio de Janeiro in June 1992, an international convention known as the 'Convention on Biological Diversity' was signed by almost all nations of the world, in recognition of biodiversity's importance and to ensure its global protection.

But what is biodiversity? In its simplest form, it is the variety and variability among living organisms and the ecosystems they populate and create. Other terms for 'biodiversity' are 'living nature', 'life', and 'creation'. Conserving this variety is considered imperative to human and non-human welfare. Clean air and water, cures for disease, and protection against a changing climate resulting from the 'enhanced greenhouse effect' are some of the benefits provided by biodiversity to human well-being. These services result from millions of years of evolution, and technological innovation has not, as yet, provided alternatives. Along with the moral, spiritual, cultural and economic reasons to conserve biodiversity, people now recognise that their own subsistence is directly related to its continued existence.

Biodiversity exists at multiple levels of biological organisation. It can be measured at the genetic level (e.g. allelic diversity); the population level (e.g. relative abundance of particular species); the community level (e.g. diversity of species); and the landscape level (e.g. heterogeneity of ecosystems)[13]. Current recommendations for biodiversity conservation focus on the need to conserve dynamic, multi-scale ecological patterns and processes that sustain all native species of plants and animals and their supporting natural ecosystems.

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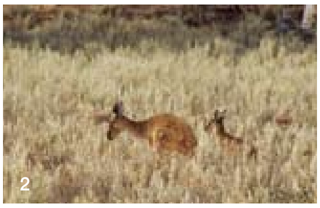

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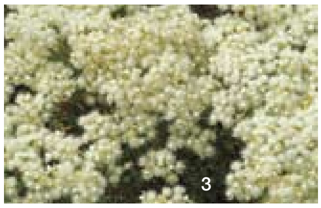

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1. Lochman Transparencies
2. Barbara Madden
3. Barbara Madden
4. The Wilderness Society

To the lucky visitor who sees the Great Western Woodlands after good winter rains, the enormous diversity of life is obvious because it is presented to them as ongoing vistas of colourful wildflowers.

CHAPTER 2

02 | The Biological Cornucopia

To the lucky visitor who sees the Great Western Woodlands after good winter rains, the enormous diversity of life is obvious because it is presented to them as ongoing vistas of colourful wildflowers. It also becomes obvious in the afternoon light—salmon gums glow orange, blackbutts white, and gimlets copper. To the lucky scientist who gets to work in this region, there can be a lifetime's work in just naming the unknown species in a particular group of animals, in understanding just one of the myriad of ecological processes, or, as we do in this chapter, describing the significance of the biodiversity found in the region.

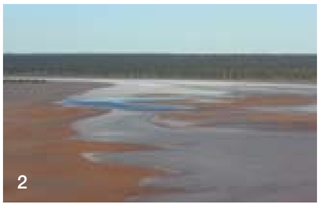
In this chapter we detail the diversity of plants and animals found in the Great Western Woodlands, the origins of that diversity, and some changes that have occurred in these communities since the arrival of Europeans. This is followed by a discussion of the role the transitional climate of the Great Western Woodlands has played in making this rich speciation possible. We conclude by outlining why the region is a high priority for conservation in Australia.

Internationally significant plant communities

The past few decades have seen the discovery, collection and description of new taxa in southwestern Australia, including the Great Western Woodlands, at a rate without parallel among the world's temperate floras[1]. Botanists are still regularly discovering species new to science. In fact, virtually every time skilled botanists look for new species in this region, they find them. It is estimated that 10–15% of Western Australia's flowering plants remain unknown to science[1]. The high degree of local speciation in this region is eclipsed in temperate zones only by that of the Greater Cape flora of South Africa[2,3,4].

Our analysis shows that the Great Western Woodlands is one of the cornerstones to south-western Australia's profound diversity of plants. The Western Australian Herbarium has records of 3314 flowering plant species from 119 families in the Great Western Woodlands and over 4200 different 'taxa'(which is a list that includes undescribed species as well as subspecies, hybrids, and varieties). It is estimated that almost half of these species are endemic to south-western Australia[1,5,6]. This is more than one-fifth of Australia's estimated 15 000 flowering plant species[7], and more than twice the number of species than occur in the whole of the United Kingdom (1500 species)[8]. It also represents a similar total number to that found in all of Canada (nearly 4000 species)—a country more than 60 times the size of the Great Western Woodlands[9]. Moreover, the two ecologically significant and iconic Australian plant groups, wattles and eucalypts, are particularly diverse in the Great Western Woodlands, with the region well-known for its variety of species[7,10].


1


2


3


4

Main image left. David Mackenzie.
1. Barbara Madden
2. Barbara Madden
3. Alexander Watson
4. Chris Dean

Since the Great Western Woodlands are still largely intact, there are fewer rare, threatened or endangered species in this region than in more disturbed areas of the state, such as the Wheatbelt. However, the Great Western Woodlands contains many species of plants that are threatened by past and present human activities. A significant number of species are already listed by the Western Australian Government as requiring special protection, and it is expected that once better surveys have been completed, these lists will expand[11]. Forty-four plant species are listed as 'declared rare flora' by the state government because they are rare, in danger of extinction, or in need of special protection. An additional 422 species have been listed as 'priority' species (Priority 1 = 129 sp., Priority 2 = 103 sp., Priority 3 = 131 sp., and Priority 4 = 59 sp.) because they are known to exist in just one or in only a few populations which are under threat, due either to small population size or to threats to the land they live on. Small population sizes may also occur because species have very restricted environmental tolerances or are adapted to rare habitats[5]. The 464 declared rare flora and priority species are distributed across the Great Western Woodlands, although the western and southern boundaries appear to contain many more species per 'half degree cell' than recorded in other parts of the region (Fig. 2.1). This could reflect sampling bias (since more sampling has been conducted in these cells), as well as the fact that this boundary abuts a landscape that has been heavily modified for agriculture.

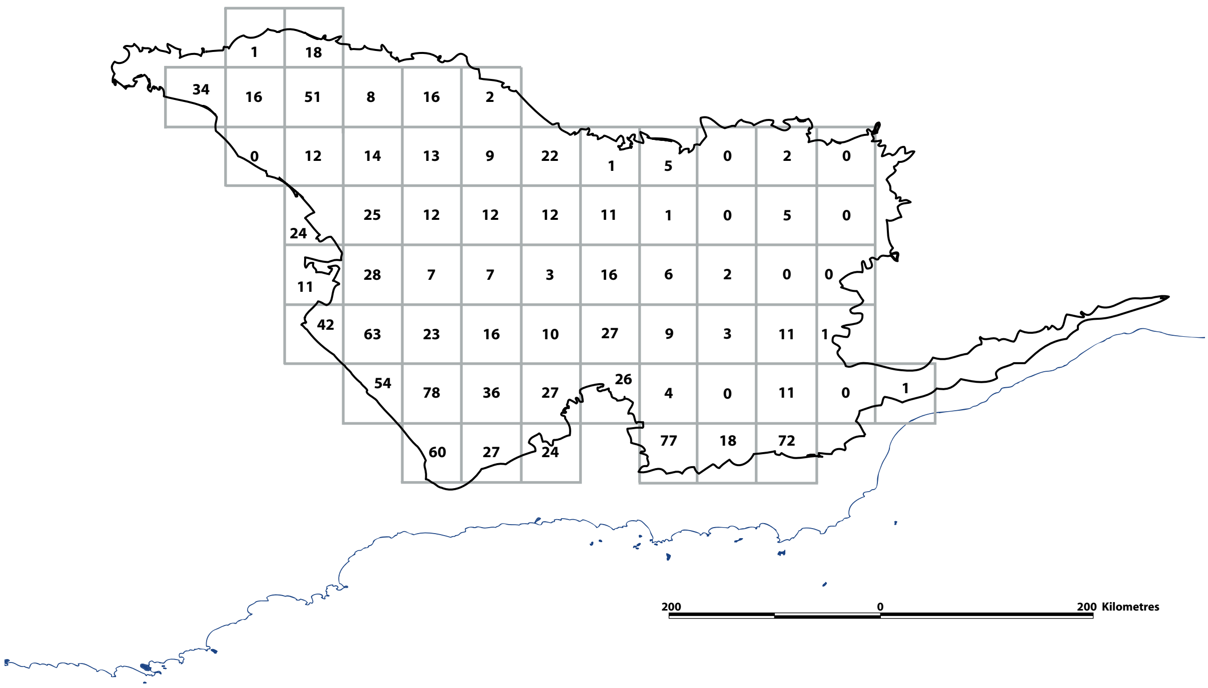


Figure 2.1

Distribution of the declared rare flora and priority plant species. We tabulated and mapped the geographical distribution of individual taxa of vascular plants species using presence and absence in a series of half degree grid cells across the region. A comparison of these cells shows that priority species are spread across the landscape. Many of these are by nature found only in tiny pockets and are threatened by a range of disturbances. It is likely that many of the rare and priority species in the western and southern parts of the Great Western Woodlands are threatened because much of the land across which they were originally distributed has been cleared for agriculture.

A tapestry of habitats

There have been several attempts to map vegetation communities in the Great Western Woodlands. The most widely used classification to date is that created by John Beard, who pioneered the mapping of vegetation at the regional scale, culminating in a series of vegetation maps across the state. Beard's mapping revealed 33 separate 'vegetation systems' in the region[12,13]. In the 1970s, he mapped these communities by grouping similar structural vegetation associations based on the dominant structural component of each vegetation community. Of these vegetation systems, 12 systems are either wholly or mostly confined to the Great Western Woodlands.

In our attempt to map major habitat types in the Great Western Woodlands, we summarised each of Beard's vegetation systems into five broad vegetation types: 'woodland', 'mallee', 'grassland', 'shrubland' and 'unvegetated' (Fig. 2.2). This analysis reveals a mosaic of these habitats within the region, with woodlands the most common type of habitat, covering more than nine million hectares. Mallee ecosystems tend to be more dominant in the southern and north-eastern areas of the region, while shrublands (also known as 'Kwongan')[5,14,15] are more common in the north and west and grasslands in the north-east. It was the shrublands[16] that scientists first recognised as being extremely diverse[5, 6,16]. Early European botanists were amazed by the subtle but significant differences within the vegetation.

More recently, the woodlands have also been recognised as containing extraordinarily diverse plant communities by global standards[1, 6, 17]. This exists both in the understorey and among the tree species.

The composition and distribution of the broad vegetation types in the Great Western Woodlands appear to be driven by multiple factors. For example, the woodlands are unique in their capacity to form relatively tall, productive vegetation under arid conditions with many endemic species and with a high degree of habitat adaptation[18]. Fires are rare in unlogged woodlands[19], but where they have occurred are often devastating and are able to change a woodland into a mixture of mallee and shrubland[20]. Kwongan shrubland also have an unusually large proportion of endemics but are different to both the woodlands and mallees because they have a high number of species that exist within very small spatial scales[5]. Another difference is that few species in Kwongan shrubland exhibit high fidelity for any one soil type[5]. In other semi-arid regions, mallee and woodland vegetation is correlated with edaphic parameters related to soil moisture and nutrients[21,22], where as the floristic variation in Kwongan shrublands have little reported correlation with soil parameters.

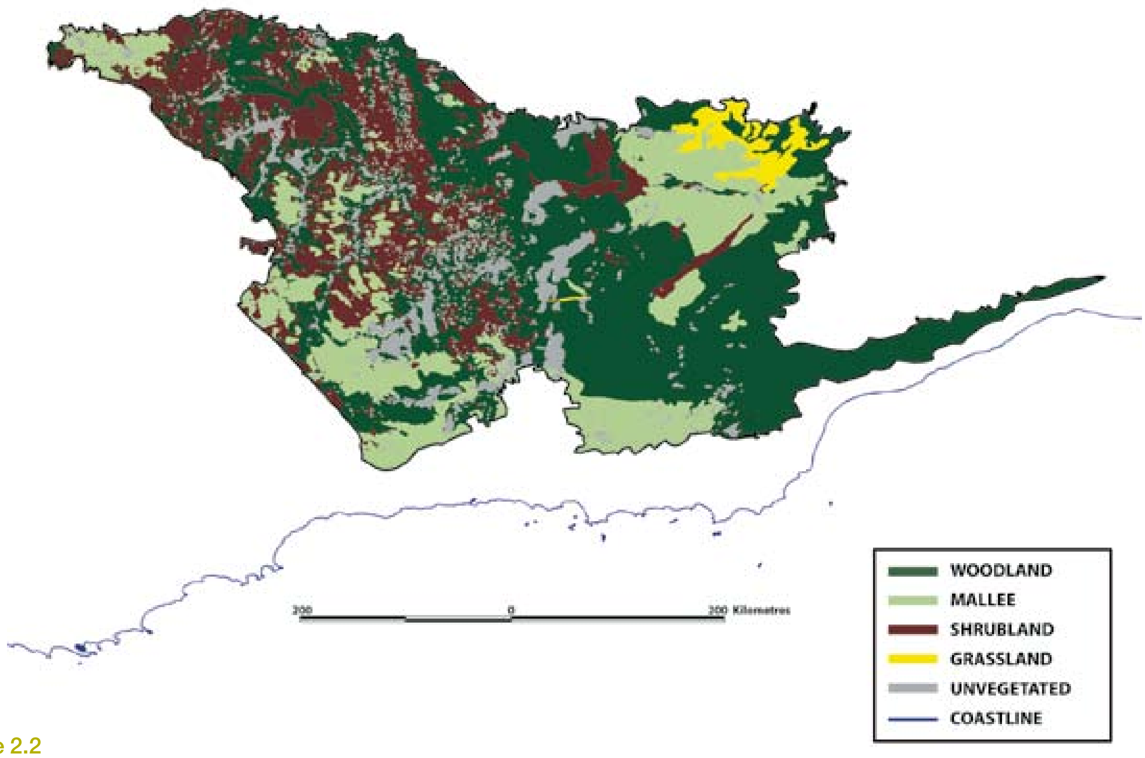


Figure 2.2

The distribution of woodland, shrubland, mallee and grassland in the Great Western Woodlands (after Beard 1980).[12] Unvegetated ecosystems are mostly salt lakes, mudflats and bare sand.

Table 2.1

The area and percentage of woodland, mallee, shrubland, grassland and unvegetated areas in the Great Western Woodlands

Broad Vegetation Type	Area in the Great Western Woodlands (ha)	Proportion of the Great Western Woodlands (%)
Woodland	8 986 723	56.2
Shrubland	3 219 093	20.1
Mallee	2 629 419	16.5
Grassland	330 479	2.1
Unvegetated*	813 189	5.1
Total	15 ,978 905	100

* Includes salt lakes and bare rocks.

Much of the diversity of vegetation across the region is impossible to display on large-scale maps. For example, there are unique plant communities on the immediate fringes of the salt lakes as well as on the small dunettes that exist in the middle of these lake systems[23]. The many granite hills, the banded ironstone hill mosaics, and the greenstone belt mosaics throughout the Great Western Woodlands are too small to appear in Figure 2.2, but each is home to unique wildlife[24,25,26,27]. The skeletal soil sheets of the inner aprons of granite exposures and hills and the heavy red sands of banded ironstone hills also represent their own vegetation systems. On these landforms, low woodlands and tall shrublands develop, dominated by She-oaks, Wattles and Broom Bush, with the occasional mallee species[29].

1

Vertebrates

The biological and structural diversity of plant communities across the Great Western Woodlands is known to provide different foraging, nesting or roosting habitat for an array of animals, even though relatively few comprehensive surveys have yet been undertaken. The Western Australia Museum (Biological Survey of the Goldfields and FaunaBase) and Birds Australia (the Australian Ornithological Club) atlas database has recorded 49 species of mammals, 138 reptile species, 14 frog species and 215 species of bird in the region.

Our research, which is based on consultants' reports, the notes of amateur enthusiasts, and the habitat requirements of species published in the peer-reviewed literature, suggests there are likely to be an additional 51 vertebrate species present in the Great Western Woodlands: 9 species of mammals, 18 species of reptiles, 6 frog species and 18 bird species. In addition to the value of the region's species richness in general, the number of different reptile species make the Great Western Woodlands exceptional among the world's reptile communities.

Many of these animal species are known to be rare and vulnerable. On the state government's rare and endangered fauna list are 32 threatened vertebrate species that either exist, or are likely to exist, in the Great Western Woodlands. These comprise 16 mammal, 8 bird and 8 reptile species. The species and the relevant legislation are listed in Table 2.2. The Wilderness Society, through a grant from the Wind Over Water foundation, conducted a vertebrate faunа survey of the Honman Ridge - Bremer Range, and found 19 species that were of conservation significance in that area alone[30].

2

1. Vegetation on Breakaways. Alexander Watson
2. Lake Cronin snake is known from very few records and is restricted to GWW. David Knowles

Table 2.2

Vertebrate species listed under the Western Australian Wildlife Conservation Act 1950 (WCA), the Commonwealth of Australia Environment Protection and Biodiversity Conservation Act 1992 (EPBC) and/or the IUCN Red List of Threatened Species 2006 (IUCN) as known to occur (c) or possibly occurring (p) in the Great Western Woodlands.

Taxon		WCA	EPBC	IUCN
Reptiles				
Aspidites ramsayi (Ramsay`s python; woma)	c	S4		EN
Echiopsis curta (bardick)	c			VU
Egernia stokesii badia	p	S1	EN	EN
Morelia spilota imbricata (carpet python)	c	S4		LR/nt
Paroplocephalus atriceps (Lake Cronin snake)	c	S1		VU
Pogona minor minima (western bearded dragon)	c	S1		
Ctenotus labillardieri (common southwest ctenotus)	c	S1		
Cyclodomorphus branchialis (common slender bluetongue)	c	S1		
Birds				
Ardeotis australis (Australian bustard)	c			NT
Burhinus grallarius (bush stone-curlew)	p			NT
Cacatua leadbeateri (Major Mitchell`s cockatoo)	c	S4		
Calyptorhynchus latirostris (Carnaby`s cockatoo)	c	S1	EN	EN
Falco hypoleucos (grey falcon)	c			NT
Falco peregrinus (peregrine falcon)	c	S4		
Leipoa ocellata (malleefowl)	c	S1	VU	VU
Psophodes nigrogularis (western whipbird)	c	S1	EN	NT
Mammals				
Antechinomys laniger (kultarr)	c			DD
Bettongia penicillata (brush-tailed bettong; woylie)	p			LR/nt
Canis lupus dingo (dingo)	c			VU
Dasycercus cristicauda (mulgara)	p	S1	VU	VU
Dasyurus geoffroii (western quoll; chuditch)	c	S1	VU	VU
Isoodon obesulus obesulus (southern brown bandicoot; quenda)	p		EN	LR/nt
Macropus eugenii (tammar ; tammar wallaby)	p			LR/nt
Macropus irma (western brush wallaby)	c			LR/nt
Macrotis lagotsis (greater bilby)	p	S1	VU	VU
Myrmecobius fasciatus (numbat; walpurti)	p	S1	VU	VU
Nyctophilus timoriensis (greater long-eared bat)	c			VU
Parantechinus apicalis (southern dibbler)	p	S1	EN	EN
Petrogale lateralis lateralis (black-footed rock-wallaby)	p	S1	VU	VU
Phascogale calura (red-tailed phascogale)	c	S1	EN	EN
Pseudomys shortridgei (heath rat)	p	S1	VU	LR/nt
Tadarida australis (white-striped freetail-bat)	c			LR/nt

Note: The Latin and common names may change with future taxonomic research.

Key to categories

Wildlife Conservation Act 1950 (WCA)
S1 = Schedule 1: Fauna that is rare or likely to become extinct; S2 = Schedule 2: Fauna presumed to be extinct;
S3 = Schedule 3: Birds protected under an international agreement; S4 = Schedule 4: Other specially-protected fauna
Environment Protection and Biodiversity Conservation Act 1992 (EPBC)
EN = Endangered; VU = Vulnerable.
IUCN Red List of Threatened Species
CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LR/nt = Lower Risk/near threatened
(LR/nt is not limited to threatened species); DD = Data Deficient

In addition, 4 species that are now globally extinct were once found in the Great Western Woodlands (the pig-footed bandicoot, the long-tailed hopping mouse, the crescent nail-tailed wallaby and the broad-faced potoroo), and a further 7 species have gone extinct from the Great Western Woodlands region and now only exist either on predator-free islands, in enclosures designed to keep cats and foxes out of them, or in very remote areas of Australia (the burrowing bettong, the banded-hare wallaby, the mala, the western barred bandicoot, the greater stick-nest rat, the plains mouse and the djoongari). In one spectacular find at Peak Charles, the bones of quolls, bandicoots, macropods, native rodents and a possum were found alongside the remains of house mice and rabbits, indicating that their presumed local extinctions have happened within the last century[31]. With improved management, it could be possible to re-introduce these animals back into the Great Western Woodlands.

Recent evidence suggests that many more species than are currently recognised on State and Federal threatened species lists are at risk of extinction and are currently experiencing significant declines in their ranges[32]. For example, up to 60% of Australia's terrestrial bird species have shown significant declines because of current land practices[33]. The preservation of the Great Western Woodlands is likely to be particularly critical to the long-term survival of birds that inhabit woodland and mallee ecosystems (e.g. Gilbert's whistler, regent parrot and malleefowl) (Box 2.1).

1. Blue Tongue Lizard. Charles Roche
2. Bones in cave. Alexander Watson
3. Hooded Plover. Stephen John Elson
4. Rainbow Bee Eater. Lochman Transparencies
5. Numbat. Lochman Transparencies
6. Western Pygmy Possum. Lochman Transparencies

Box 2.1 - Birds in the Great Western Woodlands

Professor Harry Recher

The Great Western Woodlands is a birdwatcher's paradise. Birds are abundant throughout the region, and many species of heath and woodland birds which have become scarce elsewhere in southern Australia remain common.

Land clearing and habitat fragmentation, grazing of remnant native vegetation by domestic animals, increased fire frequencies, and the abundance of foxes and feral cats, as well as the increased abundance of some native birds, such as Noisy Miners, has led to the decline of woodland and heath birds over almost all of eastern and southern Australia. Many species are now threatened with extinction, and there have already been significant losses of avian biodiversity with the extinction of populations. Nowhere is this more evident than in the Wheatbelt of Western Australia, where more than 90% of the vegetation has been cleared from most shires. According to studies by Denis Saunders and his colleagues at CSIRO, of the 195 species recorded in the Wheatbelt since European settlement, nearly half have declined in abundance since initially surveyed, while 17% have increased in numbers. No change could be shown for the other species. It is worth noting that an increase in abundance is as much a signal of environmental change and degradation is a decline to extinction.

Fortunately, the species which have declined or been lost from the Wheatbelt, such as yellow-plumed honeyeaters, Rufous treecreepers, and crested shrike-tits, remain abundant in the Great Western Woodlands.

Woodland and heath bird communities in Australia have a large number of species reliant on food resources which differ spatially in abundance between seasons and years. Hence, many of these birds are fully or partially nomadic and 'chase' their food resources over large areas. Each species is limited by the least abundant food resource through space and time. Consequently, habitat loss and fragmentation associated with habitat degradation from grazing and changed fire regimes in remnant woodlands has greater impacts on the structure of woodland avifaunas than similar levels of disturbance have on forest birds where food resources are not as variable. The intensity and immediacy of this impact-response pattern among woodland avifaunas is a significant factor in the decline of woodland birds in Australia, which can only be addressed by conservation initiatives on a spatial scale substantially greater than are currently being attempted.

This is an important part of the uniqueness of the Great Western Woodlands. The region is large enough and remains sufficiently intact enough for the birds, which rely on shifting abundances of food across the landscape to find the food they require despite seasonal and yearly changes in its distribution. Only in the Great Western Woodlands can we still see woodland and heath bird communities that have all the species that were here when Captain Cook landed at Botany Bay, and in which they can still interact with and use their environment as they have for millennia.

Retaining the birds in the Great Western Woodlands, therefore, means retaining the region itself as an ecological whole.

1. Black Shouldered Kite. Carl Danzi
2. Owlet Nightjar. Mark Godfrey


1


2

1

2

3

'The other 99%'

It is not in the scope of this report to assess other taxa. However, we can say that almost nothing is known about many elements of the Great Western Woodlands' biodiversity, except that the scale of what is yet to be discovered appears to be astounding (e.g. Box 2.2; Box 2.3). Consider that recent biological surveys of the Wheatbelt, conducted over only three years, have discovered 800 new species of spiders[34] and 30 new plants[35]. These discoveries occurred in a landscape that has been heavily disturbed. How many spider, and other invertebrate species occur in the different, intact vegetation in the Great Western Woodlands? When we understand that evolution is underpinned by levels of genetic variability and is the result of ecological processes that occur across enormous spatial and temporal scales (see Chapter 4), it makes us realise just how little we know about intact landscapes like the Great Western Woodlands. Work by the Australian National University and the Wilderness Society (under an ARC Linkage Grant) is already looking at some components of biodiversity in the region, but a much greater effort is urgently needed.

4

"Australia has the highest proportion of flower-visiting jewel beetles in the world. The Great Western Woodlands are home to over 330 species, reflecting the high floral diversity of the region. Of these beetles, over half are flower-visiting and therefore potential members of the all-important vegetation renewal team known as the pollination guild. Most flower-visiting species are found on the dominant plant family in the woodlands, *Myrtaceae*, especially on Eucalyptus, *Melaleuca* and *Leptospermum*." David Knowles.

5a

5b

1. Jewel Beetles. Charles Roche
2. Grasshopper. Chris Dean
3. Cockroach. Charles Roche
4. Jewel Beetles. David Knowles
5. Joanna Jones and Alexander Watson

Box 2.2 - The living soil: biological soil crusts

Professor Harry Recher

Walking through the Great Western Woodlands is an experience that is as much emotional and sensual as it is intellectual. Not only do you have the pleasure of being in a relatively undisturbed environment, surrounded by the sounds of birds and insects, but under your feet the soil is alive. We all know that soil is full of living organisms: insects, worms, bacteria, fungi and algae. We also know that the fertility of the soil depends on these organisms to process and recycle the nutrients falling to the ground in a rain of leaves, branches and bark from the trees and shrubs which form the woodland we see. But there is more.

In semi-arid and arid regions of the world, plants do not cover all of the ground's surface. Large expanses, in fact, have no plants growing above the ground, although their roots do extend through the soil much further than their crowns extend above it. Instead, these spaces are covered by what is called a 'biological soil crust', or 'BSC' for short. There are other names for BSC, including 'cryptogamic', 'microbiotic', and 'cryptobiotic', but all refer to the special community of organisms that grow on or just within the surface of the soil. These communities are rich in species, with more species than you can find growing above the ground, but the majority of these organisms are too small to see easily; cyanobacteria (formerly known as blue-green algae), bacteria and fungi live within the soil surface, while lichens, mosses and liverworts grow on the surface.

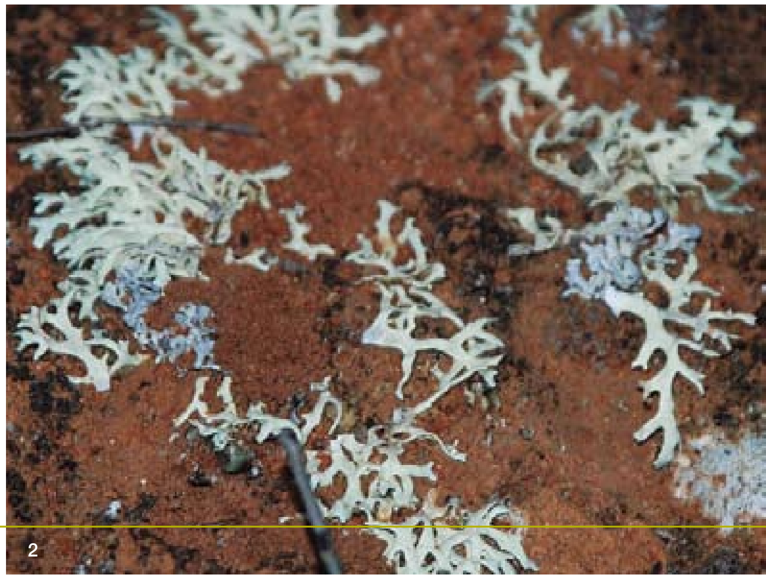
The BSC plays an important role in arid and semi-arid ecosystems. It is a site of photosynthesis, and contributes importantly to the productivity of the environment, as well as fixing nitrogen from the atmosphere, recycling nutrients and holding the soil surface together. The BSC retards the impact of raindrops and holds moisture.

It also protects the mineral elements of the soil from being blown by the wind. Without the BSC, the woodlands of the Great Western Woodlands and elsewhere would be less productive, have less wildlife, and be subject to increased erosion from rain and wind.

The BSC in the Great Western Woodlands, as in other semi-arid and arid environments, is very thin, little more than a living carpet. When it is dry, the organisms of the BSC are both dry and brittle, easily broken when trod upon or driven over. When it is wet, and the BSC is spongy, feet and vehicle tyres sink millimetres into the ground and the BSC is compacted. Although the woodlands of the Great Western Woodlands give every impression of being pristine and full of wildlife, the signs of human activity and our impact on the BSC are also easy to see. The tyre tracks of the trucks driven by sandalwood cutters, up to 80 to 90 years old are everywhere. The more recent tracks of the four-wheel drives of tourists, timber cutters and mining exploration companies are no different, and will be just as visible in 100 years as they are today.

Biological soil crusts are equally sensitive to compaction by grazing animals, including sheep, cattle and goats, and too-frequent burning. Recovery of the BSC after disturbance is measured in decades, and restoration where the BSC has been destroyed is an equally lengthy and expensive process. It is better to instead be aware of the sensitivity of the BSC in the Great Western Woodlands and manage the level of disturbance to one that does not degrade this essential component of the woodland ecosystem. Without that spring to the soil under your feet, walking through the woodlands just wouldn't be the same.

1



2

1. Keith Wood
2. Chris Dean

Box 2.3 - The invertebrates

Professor Jonathan Majer

When we consider the fauna of woodlands, we must take into account the fact that 99% of animal species on land are invertebrates. There is more to consider than just the conspicuous mammals, birds, reptiles and amphibians, which is further illustrated by the fact that, collectively, the invertebrates in a parcel of land weigh more than the vertebrates that occupy the same area.

Invertebrates play a pivotal role in the functioning of the ecosystem. Burrowing invertebrates aerate the soil and allow rain to soak in, other soil animals regulate nutrient cycling, while various insects pollinate flowers or disperse seeds. In addition to this, they provide a food source for many species of birds, mammals, reptiles and amphibians. Some of these vertebrates have specialised invertebrate diets, so they cannot survive without an adequate supply of invertebrates to feed on.

Current research in land surrounding the Great Western Woodlands is examining which restoration options are best for encouraging the return of a diverse invertebrate fauna. It is anticipated that this research will lead to recommendations for restoration options that optimise the return of biodiversity, while at the same time restoring the connectivity of the landscape. This should ensure that the biota of these woodlands is able to interact with adjoining habitats, rather than existing in isolated enclaves of land that have not been subject to clearing.

1. Chris Dean
2. Alexander Watson

Being in the Zone

One of the main reasons why the Great Western Woodlands is biologically significant is its position within the path of significant physical and biotic gradients. Being the interzone between Australia's moist, cooler south-west corner and its desert interior not only means that the region has elements of both these climatic zones, but has also created conditions to allow for enormous speciation to occur. For example, some scientists believe that variable rainfall has had a major effect on the speciation and current distribution of Australia's south-western flora[1,6].

Much of the Great Western Woodlands sits on the eastern edge of what Hopper (1979)[17] defined as the transitional rainfall zone (TRZ). The TRZ is the region of Western Australia that receives an average of between 300 and 600mm of annual rainfall per year (Fig. 2.3). As is outlined in more detail in the next chapter, this zone has experienced intense, long-term climatic pulses between wet and dry conditions, leaving the region with a very rich locally-adapted flora. Unfortunately, recent history has not been so positive for this plant diversity. Clearing much of the TRZ for agriculture has left many extinct and endangered species. The south-western and southern portions of the Great Western Woodlands now represent the largest, most intact example of these communities left.

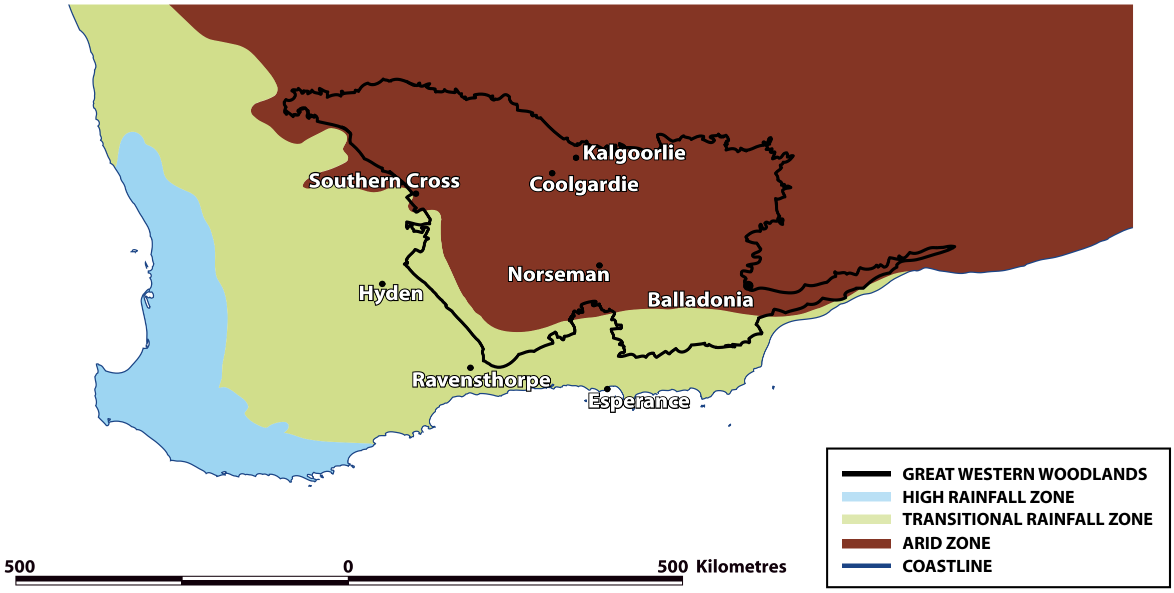


Figure 2.3

The locations of the high rainfall zone (HRZ), the transitional rainfall zone (TRZ) and the arid zone in south-western Australia. The boundary of the Great Western Woodlands is also shown.

It is no coincidence that the eastern boundary of the transitional rainfall zone correlates very closely with the Southwest Botanic Province (Fig. 2.4)–a region regarded as one of Earth's biodiversity hotspots [25] because of a combination of species richness (including endemicity) and threat [36]. Most of the Great Western Woodlands sits to the north of this boundary in what is generally described as an 'arid' climate (Fig. 2.3). However, it does not contain the typically 'Eremean' species that dominate arid regions of Australia. Instead, most of Great Western Woodlands is botanically considered an 'interzone' between the distinct floras found in the South-west Botanic Province and the Eremean Botanic Province [18]. This region is known as the 'Coolgardie Interzone' or the 'South-west Interzone' and contains a unique flora [18] (Box 2.4).

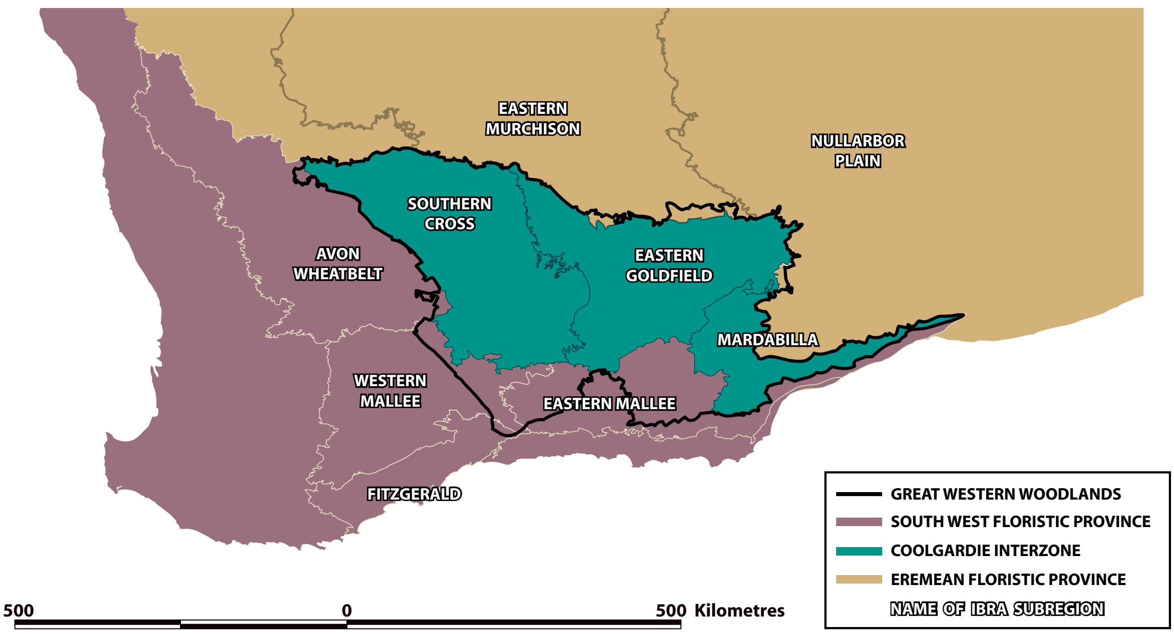


Figure 2.4

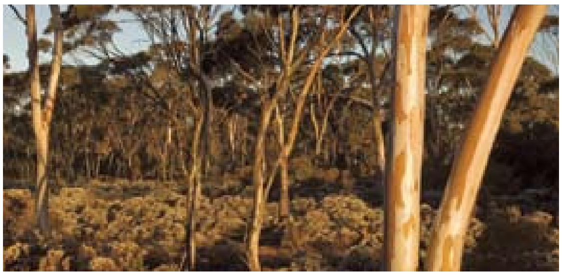
The IBRA subregions occurring in the Great Western Woodlands. The map also shows the Southwest Floristic Province and the Eremean Floristic Province. The 'Coolgardie Interzone', or South-west Interzone, is sandwiched between the two.

Box 2.4 - "All that Glisters is Gold"— eucalypts of the Great Western Woodlands

Nathan McQuoid and Sean Stankowksi

There are approximately 1095 taxa of eucalypt (comprising the genera *Angophora, Corymbia* and *Eucalyptus*) in Australia. Analysis using bioregions and subregions show there is a major centre of high species richness and endemicity in Australia's semi-arid south-west [7] (Fig. 2.5). The Great Western Woodlands is the heart of this eucalypt diversity. With data provided by the Western Australian Herbarium, the Wilderness Society conducted its own biogeographic analysis, and found that 351 taxa occur in the Great Western Woodlands—almost one-third of Australia's taxa. This profound diversity is represented in the mosaic of canopies visible from the granite domes rising above the subdued landscape. As you drive through the Great Western Woodlands, a rich pattern of woodland and mallee eucalypt varieties emerge, from salmon gums, black morrels and bronze mallets, to silver gimlets, frosted gums and copper mallees. The area is a marvel of not only form and colour diversity, but also enormous species number.

Within Australia's south-west, eucalypt richness and endemism are largely determined by rainfall[37]. High rainfall areas are typically associated with low diversity[37], whilst areas that receive lower rainfall, particularly those associated with the transitional rainfall zone, exhibit high diversity[38]. The high number of species in the Great Western Woodlands is attributed to fluctuation in climatic regimes across the region over a very long period of time, resulting in vigorous adaptive responses and consequent speciation[37] (see Chapter 3 of this report). As the Great Western Woodlands is the last intact remnant of temperate woodland that falls on the transitional rainfall zone, this area would be expected to, and does, exhibit eucalypt species diversity and endemism which is second to none.



Mark Godfrey

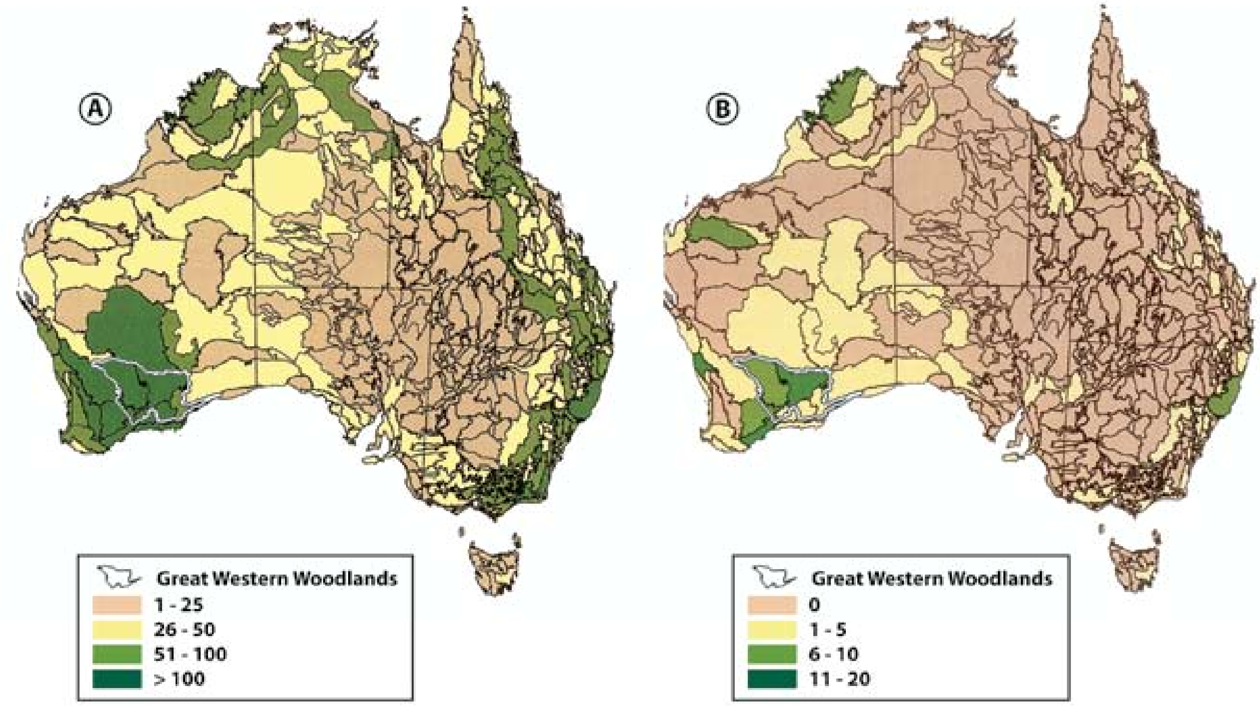


Figure 2.5

Map of Australia divided into IBRA subregions showing (a) the species richness of Eucalypt species within each subregion and (b) the number of endemic species to each subregion (e.g., species that are only found within one each subregion).

This 'interzone' between the cooler, wetter south-west and the hotter, drier interior is also evident in the vertebrate fauna. For example, the mammal, amphibian, reptile and bird faunas all have species characteristic of the humid south-west or the desert[39]. A significant proportion of these species are at the geographical limits of their ranges within the Great Western Woodlands. For example, some south-western endemic species (e.g. honey possums, western brush wallabies, red-capped parrots and western spotted frogs) are found in the far south-west regions of the Great Western Woodlands. Other Western Australian endemic species are at the limit of their south-eastern distribution in the Great Western Woodlands (e.g. little long-tailed dunnarts, ash-grey mice, and western mice). Continentally distributed desert species are found in the north-east of the Great Western Woodlands (e.g. the inland broad-nosed bat, the Sandy Inland mouse, the pied honeyeater and Wilsmore's frog).

1. Elegant Parrot. Stephen John Elson
2. Honey Possum. Lochman Transparencies
3. Pied Honeyeater. Stephen John Elson
4. Woodlands link the moist South West to the inland deserts. Barbara Madden

Bridging botanic boundaries

The Great Western Woodlands' position as part of an 'interzone' has meant that over the past century biogeographers have drawn various boundaries over the region in an attempt to identify taxonomically and ecologically-distinctive biogeographic regions[6,40]. The most recent attempt, and the boundaries currently recognised by state and federal departments, is the 'Interim Biogeographic Regionalisation for Australia' ('IBRA')[41] . This Australia-wide approach categorised the continent into regions of like geology, landform, vegetation, fauna and climate. IBRA was designed as a temporary geographic framework for ecological and conservation assessment, and is based on the recognition that physical processes drive ecological processes, which in turn drive patterns of biodiversity[41]. There are 80 IBRA regions throughout Australia; their boundaries and the corresponding mapping has formed a substantial basis for conservation priorities in Australia[42].

In Western Australia, Beard's phytogeographic map of Western Australia, a hierarchical system of provinces comprised of botanical districts and subdistricts[12], formed the baseline data set for IBRA. Twenty-six IBRA regions are now recognised in Western Australia. The Great Western Woodlands falls mainly into two IBRA bioregions—Coolgardie (Southern Cross, Eastern Goldfields and Marabilla subregions) and Mallee (Eastern and Western Mallee subregions)—and includes very small areas of the Avon Wheatbelt bioregion and the Esperance Plains bioregion (Fitzgerald subregion). Both Beard's floristic provinces and the IBRA subregions are shown in the context of the Great Western Woodlands in Figure 2.4.

The two principal IBRA bioregions in the Great Western Woodlands have different histories with respect to human activities. The Mallee bioregion is one of Western Australia's most biodiverse subregions. It has also been heavily modified by Europeans—more than 75% has been cleared for agriculture. The situation in the Coolgardie bioregion is different. The vegetation there is largely uncleared, and the bioregion contains 14 wetlands of regional significance.

A continent-wide priority

The Great Western Woodlands is continentally significant because it represents the largest intact landscape of its type left in Australia. An analysis of Australia's vegetation by the Australian Government in 2002 showed that four broad vegetation groups found in the Great Western Woodlands—called 'eucalypt woodlands', 'eucalypt open woodlands', 'mallee woodlands and shrublands' and 'acacia forests and woodland'—have been substantially cleared in other regions of Australia (Table 2.2) [43,44]. In the Great Western Woodlands, these four ecosystems remain largely intact. (Table 2.3). An additional ten vegetation groups also occur in the region, meaning that the Great Western Woodlands contains more vegetation groups than iconic areas such as Kakadu and Cape York. In fact, with the exception of Tasmania (which contains 15 vegetation groups), there is no other area in Australia of equivalent size to the Great Western Woodlands that has as many vegetation groups.

Chris Dean

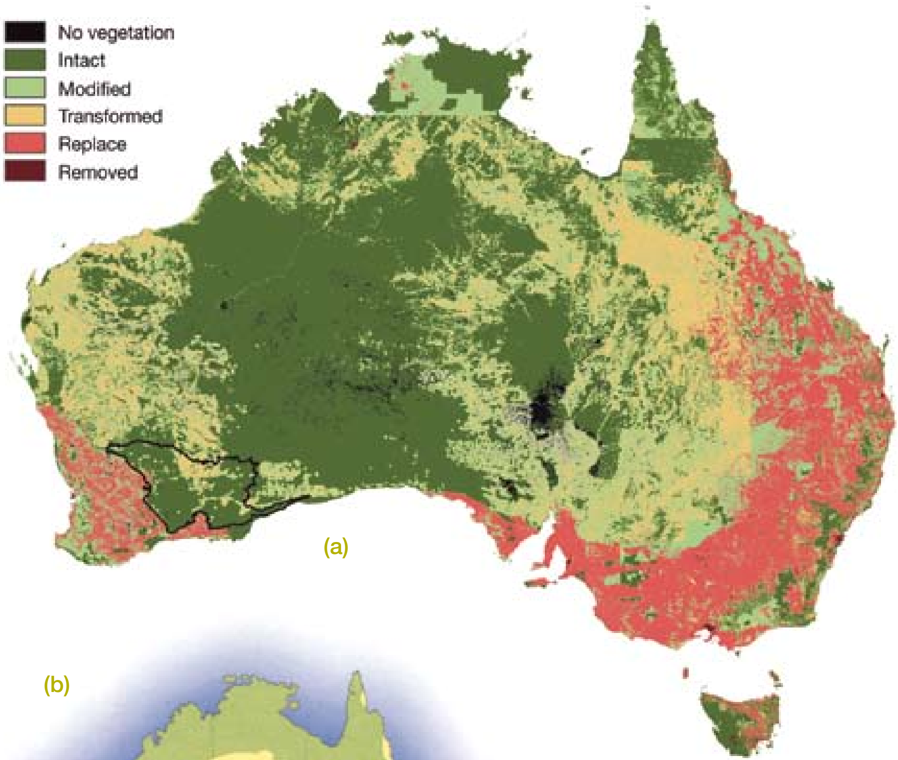
Table 2.3

The land cover of each of the Australian Native Vegetation Assessment's 23 major vegetation groups found in Australia prior to European inhabitation (i.e. pre-1788) versus those found in 2001.

Major Vegetation Group	Total Cover in Australia pre-1788 (km^2)	Total cover in Australia 2001 (km^2)	Proportion of 1788 cover now cleared (%)	Area in the Great Western Woodlands (kms)	Proportion of the Great Western Woodlands Occupied (%)
Eucalypt woodlands	1 012 047	693 449	31.4	83 738	52.41
Mallee woodlands and shrublands	383 399	250 420	34.7	27 497	17.21
Low closed forests and tall closed shrublands	15 864	8 749	44.9	10 501	6.57
Acacia shrublands	670 737	654 279	2.5	7 499	4.69
Inland aquatic—freshwater, salt lakes, lagoons	NA	-	-	6 171	3.86
Other shrublands	115 824	98 947	14.6	5 280	3.3
Hummock grasslands	1 756 962	1 756 104	0.1	3 322	2.08
Heathlands	47 158	25 861	45.1	3 051	1.91
Acacia forests and woodlands	657 582	560 649	14.7	3 001	1.88
Casuarina forests and woodlands	73 356	60 848	17.1	2 279	1.43
Chenopod shrublands, samphire shrublands and forblands	563 389	552 394	2.0	2 277	1.43
Cleared, non-native vegetation, buildings	NA	-	-	2 243	1.4
Naturally bare—sand, rock, claypan, mudflat	NA	-		2 036	1.27
Acacia open woodlands	117 993	114 755	2.7	643	0.4
Eucalypt open woodlands	513 943	384 310	25.2	156	0.1
Callitris forests and woodlands	30 963	27 724	10.5	49	0.03
Eucalypt low open forests	15 066	12 922	14.2	44	0.03
Rainforest and vine thickets	43 493	30 231	30.5	0	0
Eucalypt tall open forests	44 817	30 129	32.8	0	0
Eucalypt open forests	340 968	240 484	29.4	0	0
Melaleuca forests and woodlands	93 501	90 513	3.2	0	0
Other forests and woodlands	125 328	119 384	4.7	0	0
Tropical eucalypt woodlands/grasslands	256 434	254 228	0.9	0	0
Tussock grasslands	589 212	528 998	10.2	0	0
Other grasslands, herblands, sedgelands and rushlands	100 504	98 523	2.0	0	0
Mangroves	112 063	106 999	4.5	0	0

Analysis of the Vegetation, States and Transitions (VAST) framework that was produced by the Federal Government[45] also reveals the region's continental significance (Fig. 2.6). If the very large arid interior which includes landscapes including the Great Victoria Desert and the Nullabor Plain are excluded from their analysis, the Great Western Woodlands is readily observed as the largest intact landscape in southern Australia. Recent analysis by the Centre of Ecology at the University of Queensland also revealed that the Great Western Woodlands should be considered a 'high priority' with respect to future conservation efforts in Australia[46] (Box. 2.5). Their analysis shows that managing this landscape would be one of the most cost-efficient ways to conserve biodiversity on the continent.

Internationally, the region is also becoming recognised as a significant asset to the world's biodiversity.
For example, with respect to the world's 'Mediterranean Biomes' (a biome is a climatically-defined area or areas with similar communities of plants and animals), this region contains the largest intact area of Mediterranean woodland in the world (Box 2.6). Unlike other Mediterranean ecosystems where our human footprint has been heavy, the Great Western Woodlands remains a relatively undisturbed mosaic of natural ecosystems.



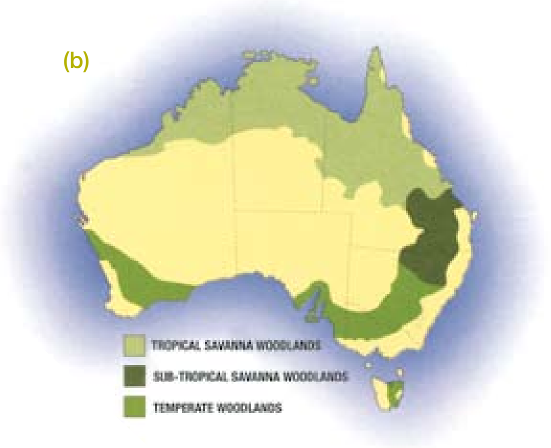


Figure 2.6

(a) The relative condition of Australia's vegetation condition (modified from Thackway and Lesslie 2006)[45].
The dark green colour that predominates in the Great Western Woodlands suggests that the vegetation has not been significantly affected by post-European land use change.

(b) The distribution of temperate, sub-tropical and tropical woodlands in Australia (modified from Australia Conservation Foundation 2000).[46]

Box 2.5 - Continental prioritisation

Dr Kerrie A Wilson, Carissa J Klein, Professor Hugh Possingham, Josie Carwardine, Matt Watts and many others

Recent analyses undertaken at the University of Queensland have identified the Great Western Woodlands as a continental priority for both the conservation of biodiversity and the protection of large and intact landscapes[47]. The aims of the analysis were to:

1. Identify and prioritise large areas of intact vegetation for conservation investment.
2. Comprehensively represent a wide spectrum of biodiversity features using the best national-scale, publicly-available biological data available for Australia, including major vegetation types, environmental domains, and bird and threatened species distributions.
3. Account for the principle of complementarity, which is the contribution of currently protected areas towards the biodiversity of areas not currently protected.
4. Ensure the priority areas identified were cost effective, where the cost represents the cost of acquiring all areas of native vegetation within each sub-catchment, determined from the average unimproved land values in each local government area.

This research identified spatial priorities for conservation investment that minimize the cost of acquiring land, subject to the constraint that biodiversity and wilderness conservation objectives must still be able to be achieved. We seek to reach wilderness conservation goals by placing an emphasis on conserving clusters of intact sub-catchments (i.e. groups of adjacent sub-catchments), with the objective of identifying large, intact areas. To achieve biodiversity conservation objectives, we identify areas that comprehensively represent a wide spectrum of biodiversity features. Our analysis shows the Great Western Woodlands to be critical to the protection of biodiversity and intact vegetation in Australia.

Box 2.6 - The largest intact area of Mediterranean woodland habitat in the world

Dr Kerrie Wilson and Kirk Klausmeyer

The forests, woodlands and scrub habitats of the 'Mediterranean' biome comprise five main regions: the Mediterranean Basin, and portions of California/Baja California, South Africa, Australia and Chile (Fig. 2.7). Mediterranean habitats are characterised by unique soils, topography, geography, and climate (hot, dry summers and cool, wet winters). These habitats are also renowned for their high levels of both endemic biodiversity [48,49] and threat[50]. Mediterranean habitats have had a long history of human influence and undergone much anthropogenic modification. Many of the Earth's most prolific civilizations, including the ancient Persians, Romans, Egyptians, and Greeks, are of Mediterranean origin. Over 40% of the area of this biome has been modified[51], and there is ongoing loss and degradation of habitat through development, population growth, and the conversion of native vegetation for urban and agriculture development. Less than 5%of the remaining habitats are protected[51].

As a consequence, the Mediterranean biome consistently emerges as a global priority for biodiversity conservation[51].

While occupied by Indigenous persons for over 40 000 years, Australia was settled by Europeans relatively recently—a little over 200 years ago. In this short time, over 35%of the Mediterranean habitat has been cleared for agriculture and urban development. The remaining fragments of habitat are susceptible to overgrazing, salinisation and edge effects. Nonetheless, Australia also boasts the largest intact area of Mediterranean woodland habitat in the world. The Great Western Woodlands of south-western Australia cover more than 160 000 km^2. Almost 100 000 km^2 of this region is unallocated crown land. If the unallocated crown land in these woodlands were afforded greater protection, then the overall level of protection of Mediterranean habitat in Australia would increase from 10% to 25%, creating the largest protected reserve of Mediterranean-type habitat in the world.

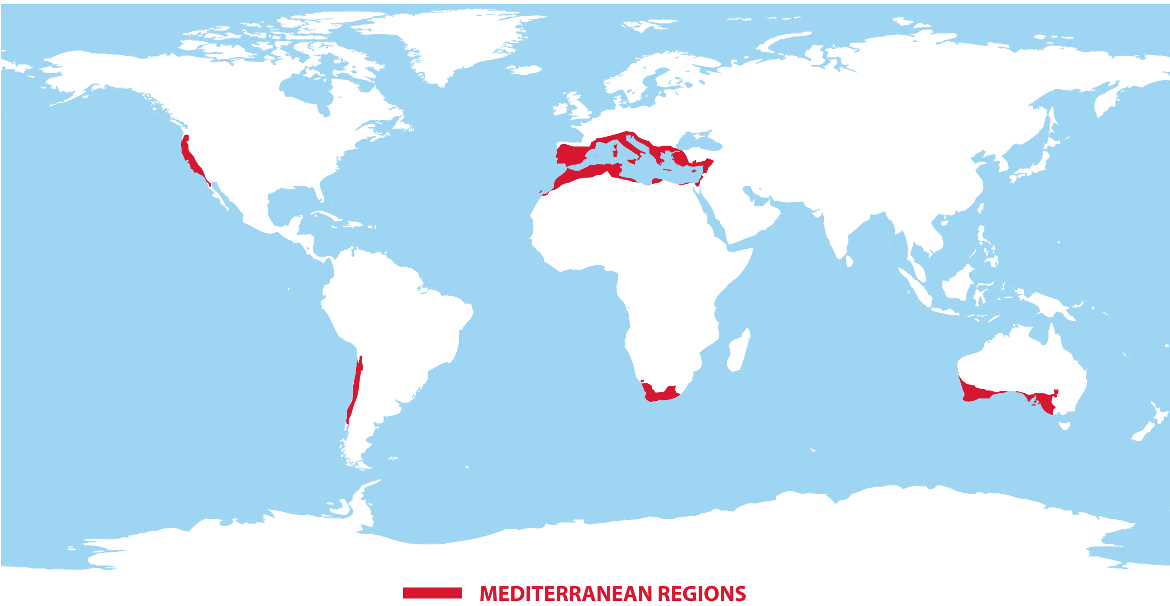
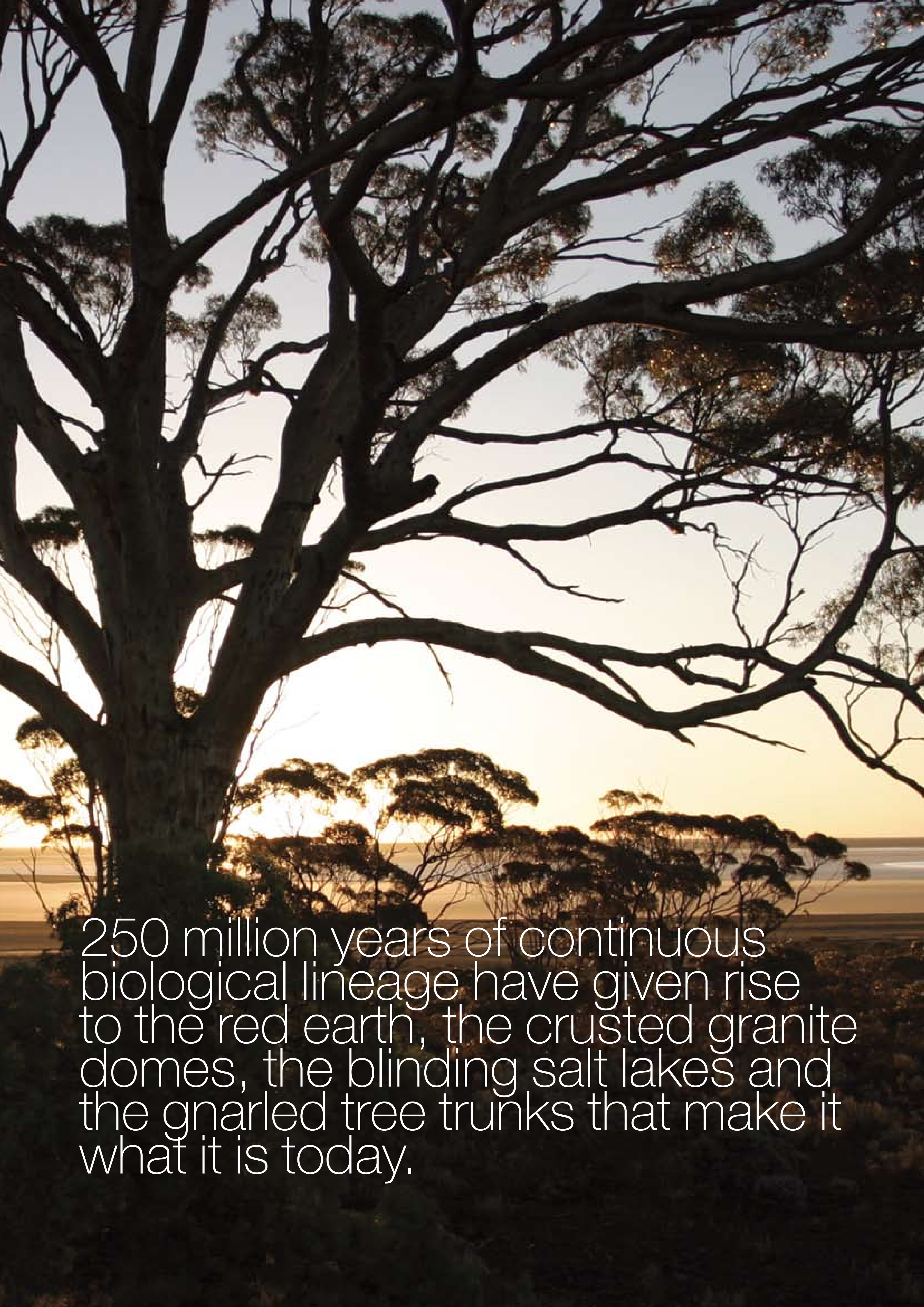


Figure 2.7
Global distribution of the Mediterranean biome

Conclusion

The Great Western Woodlands is of global biological significance. The diversity of the region has three key features. First, there are extraordinarily high numbers of species. Second, the taxonomic composition and structure of ecological communities vary greatly over short distances across the landscape. Third, the ecological processes which allow such richness and biomass to persist under such semi-arid and infertile conditions are remarkable. Much more research is required to fully understand these processes, as is outlined in Chapter 4 of this report.

This chapter also reveals the region as a unique haven for a community of animal species that are now threatened elsewhere in Australia. This is because similar habitats in Western Australia and through much of southeastern Australia have been heavily fragmented and cleared. While our analysis highlights how remarkable the Great Western Woodlands is from local, state, national and international perspectives, the continuing biological discoveries there underscore how much more we have to learn about the biodiversity of the region.



250 million years of continuous biological lineage have given rise to the red earth, the crusted granite domes, the blinding salt lakes and the gnarled tree trunks that make it what it is today.

CHAPTER 3

03 | An Ancient Landscape

Panoramas of the Western Australian landscape are not only testament to photographers' skills, but are also a tribute to the natural forces that have been at play across that landscape over an incredibly long period of time. In the Great Western Woodlands, 250 million years of continuous biological lineage have given rise to the red earth, the crusted granite domes, the blinding salt lakes and the gnarled tree trunks that make it what it is today.

This chapter describes the formation of the Great Western Woodlands' landscape, explaining how this region came to contain a highly-adapted and diverse biota. The physical formation of the Great Western Woodlands' landscape—the stage on which the evolution of unique plants and animals has played out—is a remarkable story. We end the chapter by examining the region's climate history, and show that the regions diversity is driven by its unique location as the transition zone between the wetter southwest and the arid interior.

Opposite main image. Charles Roche
Below. Natural salt lakes that were once large Amazon like-rivers. Barbara Madden

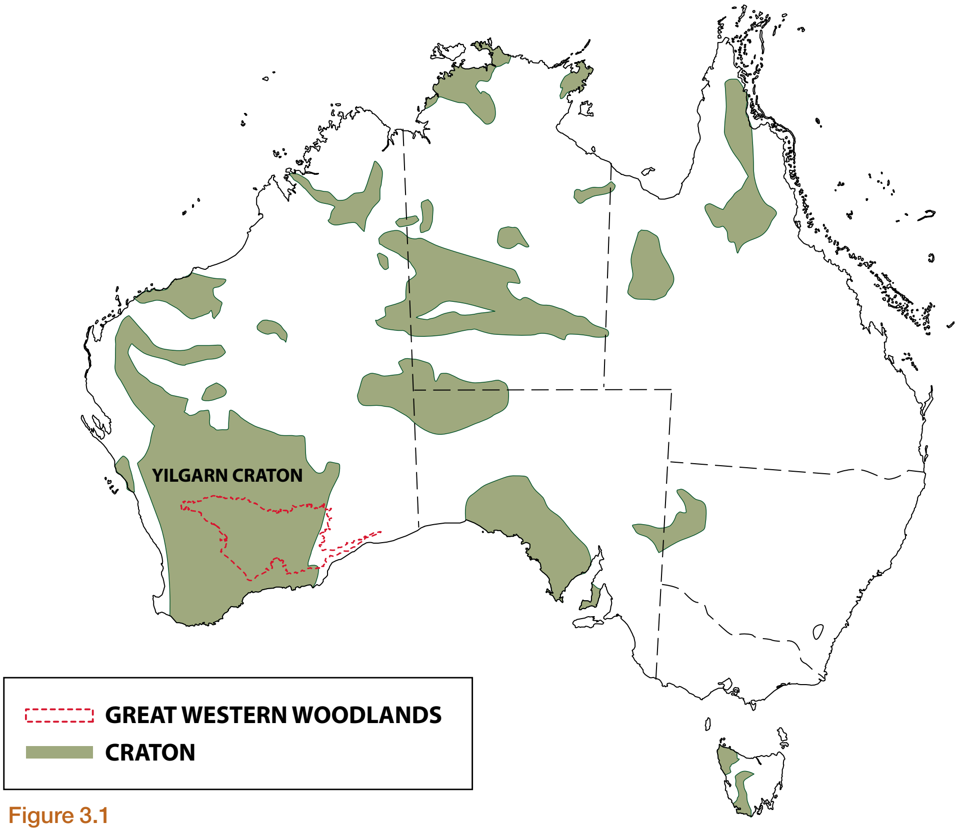


Figure 3.1

The distribution of cratons in Australia (modified from White 1986)[4]. The vast majority of the Great Western Woodlands sits squarely on the Yilgarn Craton.

The Great Western Woodlands' great age

Terrestrial ecosystems reflect the dynamic interplay over time between geological substrate, topography, and native plants and animals. As a result, landform, soil type and vegetation are strongly correlated, producing recognisable patterns of land systems. The vast majority of the Great Western Woodlands sits on part of a large (650 000 km^2), geologically stable formation that formed between 2400 and 3700 million years ago [1,2] (Fig. 3.1). This formation is known as the 'Yilgarn Craton'—yilgarn being an Aboriginal word for quartz and 'craton' coming from the Greek kratos for 'strength'. Cratons are one of the oldest and most stable land masses on the planet. The Yilgarn Craton contains some of the oldest mineral deposits ever recorded on the earth's surface[3]. The Yilgarn Craton has a complex geology. It formed originally when vast seas of molten rock ('magma') erupted at the earth's surface before cooling and hardening. Later, new molten rock beneath this granite was forced upwards under pressure. With different chemical constituents, different pressures, and a different cooling regime, this created intrusions of different rock types—a geological mosaic[1,5]. An example of these intruded rocks is the parallel greenstone belts that run SSE-NNW across the Great Western Woodlands [6,7]. These greenstone intrusions occurred soon after the formation of the Yilgarn Craton and contain large quantities of gold and nickel (Box 3.1). As such, most of the exploration for minerals in the Great Western Woodlands occurs along these greenstone belts. As outlined in the previous chapter, this complex geology has profound implications for the numbers and types of plants and animals found across the Great Western Woodlands.

Peak Charles, at 651m above sea level, is the highest peak in the Great Western Woodlands. This towering syenite rise is an example of intrusion in the Yilgarn Craton.

1. Peak Charles. Chris Dean
2. From the summit of Peak Charles. Charles Roche

Box 3.1 - The Woodland greenstones

Nathan McQuoid

The greenstones underlying the Great Western Woodlands offer a paradox of mineral and natural wealth (Fig. 3.2). Mostly basaltic lavas, they are celebrated in southern Western Australia as the source of large amounts of the state's huge mineral wealth [8]. Kalgoorlie, Coolgardie, Leonora, Ravensthorpe and other well-known places owe much of their story to the gold, nickel and copper that lie beneath.

These greenstones significantly impact the landscape by providing more mineralised and richer soils, often with laterised tops and gravel slopes on their low rises. They are intrusions of sedimentary and volcanic rocks into (and out of) the surrounding gneiss of the massive Yilgarn Craton, and bring new soil types and low hills to the Great Western Woodlands. As a result, they are islands across a vast plain where a distinctive flora has evolved. For example, woodland system diversity reaches a zenith on the richest parts of the greenstones, where uncommon species such as the woodland ghost gum *(Eucalyptus georgei)*, the copper/bronze mallet (*E. prolixa*) and Dundas mahogany *(E. brockwayi)* (which is barely distinguishable from salmon gum (*E. salmonophloia*), are interspersed among more common systems such as Dundas blackbutt *(E. dundasii)* and the silver gimlet *(E. ravida)*.

Given that there is extraordinary mineral and biological wealth found on the greenstones, very careful stewardship is required if their natural heritage and intense character is

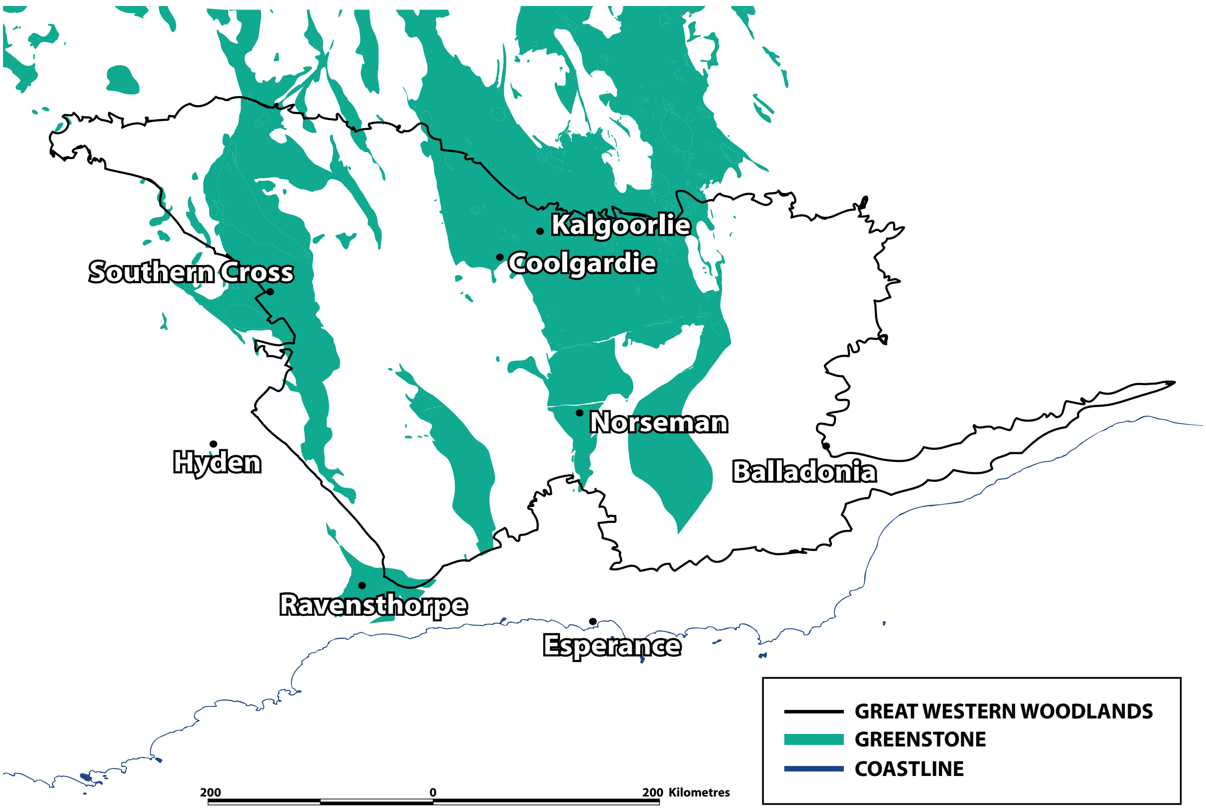


Figure 3.2
The occurrence of greenstone in the Great Western Woodlands.
The data for this map came from the Western Australian Department of Mineral and Resources.[9]

As one would expect, over the 2400 million years since it formed, the landscape of the Yilgarn Craton has changed dramatically. For example, about 1300 million years ago, continental drift pushed the Craton into another landmass, producing a huge thickness of crumpled crust similar to that which formed the Himalayas when India collided with Asia[1]. Later, the formation of the super-continent 'Gondwana' (530–550 million years ago[9]) created large mountain ranges. These ancient mountains have long since eroded away, their sediments forming vast sandplains and river flats[10]. The Porongorup Range, found to the south-west of the Great Western Woodlands, is the eroded stump of one of these ranges[10] (Plate 3.3). So much erosion occurred at this time because the landscape was devoid of vegetation—terrestrial plants had not yet evolved.

The appearance of life

The first life crawled from the sea and colonised the land while what is now the Great Western Woodlands was part of the Gondwana super-continent (Fig. 3.3). This land mass was already ancient when the earliest land plants appeared some 430 million years ago, insects evolved about 390 million years ago, reptiles evolved 330 million years ago, mammals evolved 230 million years ago and flowering plants evolved 120 million years ago[11,12]. The land itself has been stable since before mammals appeared—no ice sheets or mountain building episodes to sweep it clean. Today's Great Western Woodlands reflects a continuous biological lineage stretching back some 250 million years. As a result, the animals and plants of the Woodlands still share a common heritage, from Gondwanan times, with many plants and animals on other continents.

1. Peak Charles. Chris Dean
2. Cave Hill. Andy Wildman
3. Tadpoles are found on the very top of granite domes. Alexander Watson

Figure 3.3

A map of the Gondwana super-continent approximately 120 million years ago. The map shows the relative position of the area now occupied by the Great Western Woodlands (modified from White 1986) [4].

A land of modest mountains

Like much of inland Australia, the Great Western Woodlands is a land in low relief. If you choose to explore this region by heading east along the Hyden-Norseman Road, you will eventually see the sun set in your rear-view mirror and notice that the horizon is nearly perfectly flat, so much so that modest granite rocks appear as mountains. This striking but subtle flatness is a testament to eons of land erosion(Fig. 3.4).

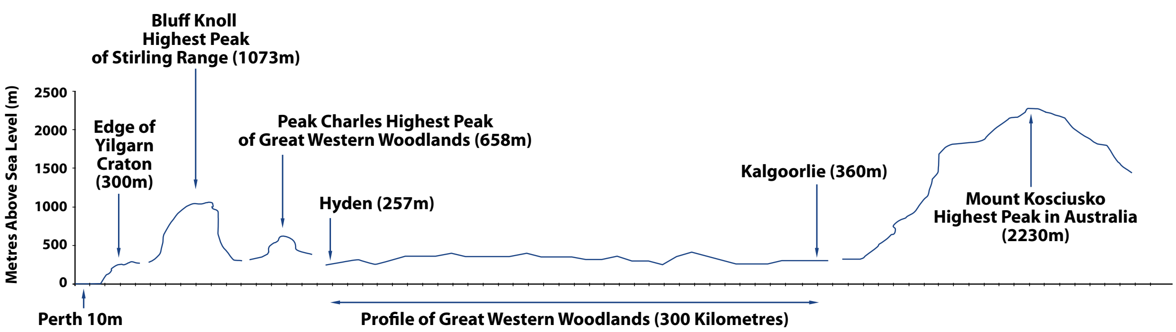


Figure 3.4

A schematic representation of the elevation across a section of the Great Western Woodlands. The heights of Australia's highest mountain (Mt. Kosciusko) and Western Australia's highest mountain (Bluff Knoll) are included for comparison.

A prime event in the Great Western Woodlands becoming a gently undulating landscape was the massive glaciation that occurred between 250 and 330 million years ago. Known as the 'Permo-Carboniferous Glaciation', this event was characterised by an enormous ice-sheet that covered most of Australia, standing in some parts a kilometre thick and ultimately flattening a number of mountain ranges. This was the last major landscape-changing event that the Great Western Woodlands experienced[14].

McDermid Rock. Barbara Madden

Therefore, for approximately 300 million years, the Great Western Woodlands has been undisturbed by glaciation—an incredibly long period to remain unglaciated. In the northern hemisphere, in contrast, there have been several major ice ages in the last two million years[15]. In fact, much of North America (the 'Wisconsin glaciation'), Britain and Northern Ireland ('Devensian' and 'Midlandian' Glaciations), and northern Europe ('Weichsel Glaciation') had glaciations that ended as recently as 10–20 000 years ago[16,17,18].

Most of the Great Western Woodlands has also remained undisturbed through many episodes of global sea level change. In between eras of global glaciation, the ice melts, water flows to the sea, and sea levels rise, inundating large areas of land. Marine-derived sediments at Kambalda and Norseman indicate that seawaters once lapped near the middle of the Great Western Woodlands[2]. However, most of the region stayed above the waves, even during the maximum sea level rises onto the Australian continent[2,18].

Box 3.2 - Granite outcrops a microcosm of the Great Western Woodlands

Anya Lam

'Towering 500 m above the surrounding plain, Peak Charles is visible for more than 50 kilometres in all directions. From the Peak Charles lookout, a two kilometre climb, there are sweeping views over the surrounding dry sandplain heaths and salt lake systems, and the view from the top reinforces the feeling of being on an island' [22]

The subdued landscape of the Great Western Woodlands is punctuated by granite outcrops which form landmarks by which Indigenous people and Europeans travelled[23]. The most prominent are the inselbergs: cone-shaped granite peaks (such as Peaks Charles and Eleanora) which stand in isolation and rise suddenly from the surrounding plains[5]. Throughout the Great Western Woodlands, the extreme flatness makes even low granite rises such as Cave Hill (90m in elevation) prominent in the landscape.

The granite exposures of the Great Western Woodlands are a special delight for geologists because of the variety of landforms they encompass [24]. McDermid Rock, situated on the northern tip of Lake Johnston, forms a classic example. It showcases all manner of minor granite landforms including gnammas, islands of vegetation on shallow soil veneers, balancing boulders, and tafoni: large-scale honeycombs of hollows that develop as inverted saucer shapes on the underside of boulders[24].

Within the vast, dry matrix of the Great Western Woodlands' ecosystems, granite outcrops form islands of unique habitat for both plants and animals. On outcrops, the shallow skeletal soils are prone to both waterlogging and rapid drying because of their thinness. This forms a harsh environment that lends license to only the most specialised plants. Eucalypt growth is hindered, causing the growth of low woodlands and tall shrublands dominated by she-oaks, wattles and broom bush. A few species of mallee can also grow. Runoff forms a halo of damp soil fringing the granite during winter [20,21], creating another distinctive plant habitat for more moisture-adapted species. Botanical surveys indicate that the vegetation mosaics found on and around granite outcrops are unique, and result from an increasing drying of climate since the late Tertiary (65 million years ago to 1.8 million years ago).

Worn away

In the past 250 million years, the Great Western Woodlands' landscape has flattened due to the erosive action of wind and rain. The subtle rises and falls of low ridges and broad valleys, the shallow granite domes, the extensive sandplains, and the round-topped ironstone hills all reflect the long-term weathering of the landscape [19,20,21] (Box 3.2). The sandplain terrain is a clear example; it rises and falls gently across these plains with less than a 2 degree inclination on its slopes. Shallow sands and gravely sands predominate on the rises, while deep sands, deposited by erosion further up the slope, can exist lower in the landscape. The sands are now acidic, well-drained and leached of nutrients[20,21].

Breakaways—distinctive features of Western Australia's ancient inland—are an occasional interruption to the gentle sandplain surface. They are squat escarpments that truncate the land, forming vertical windows into its geology and exposing the deeply-weathered profile that underlies the sandplains (Plate 3.4). Breakaways are thought to have formed as a result of chemical reactions between rainfall, decomposing vegetation, and the underlying rock beneath the sandplains[2]. As such, their presence is a reminder of a past climate that was warm and humid, and that rainforest once covered what is now the Great Western Woodlands.

1. Lake Johnston Drying. Alexander Watson
2. Breakaways. Alexander Watson

1

2

The gradual drying

The Great Western Woodlands is now a dry place most of the time. Water is scarce, there are no permanent streams or rivers, and even the extensive salt lakes are nearly always dry, and only centimetres deep when 'full'. For much of the year, if you were to get out of your car and venture into the woodlands, you would hear leaves crunch underfoot. While making a billy of tea, you would notice that insects were attracted to any water you had lying around. And when you washed your kettle and cup and disposed of the water, you would see the soft and friable soil act like a sponge and suck up all the offered moisture.

It was not always this way. This was once a very wet place, and the process of drying helped to create the amazing variety of life now found across it. But it's a long story.

About 160 million years ago, the Gondwanan super-continent began to break up. First India and then Antarctica split from Australia. At this time, Gondwana was positioned over the South Pole and the entire super-continent was covered in rainforest. For much of this time, giant rivers the equivalent of today's Amazon ran west into the Indian Ocean and east into the Southern Ocean. Large flows of water incised narrow deep channels into the bedrock and left broad valleys across the landscape[25].

But nothing lasts forever, not even 100 million years of warm, wet climate. Aridity started to increase 21 million years ago, a drying trend that still continues today[2]. Where rainfall remained higher and more reliable, the formation of breakaways continued. In drier inland regions, the ageing soils, combined with changes in vegetation as the landscape dried, contributed to landscape instability, and erosion and deposition ensued. This left today's Great Western Woodlands as a dissected landscape, with a montage of soils and landforms not seen closer to the wetter coast[18]. The rivers dried up and remain buried to this day under well-drained, deep soils [20,21]. Chains of salt lakes now indicate where these broad valleys once ran across the landscape[22] (Box. 3.3).

Box 3.3 - Salt lakes in the Great Western Woodlands

Bindy Datson

Salt lakes in the Great Western Woodlands are remnants of ancient drainage systems (Palaeochannels or Palaeodrainage systems) that originated in the late Cretaceous period about 65 million years ago. These drainage systems generally flowed north to south and eventually discharged into the ocean at the Great Australian Bight. As the land surrounding them eroded away, the drainage channels filled with sediments, resulting in the saline playas that we see today. The Palaeodrainage systems now terminate beneath the Nullarbor; none actually reach the ocean. The systems that underlay the salt lakes in the Great Western Woodlands are called the Cowan and Lefroy systems.

These salt lake systems appear to be large expanses of bare salty mud with not much chance of supporting any sort of life. For a large part of the year the saline playas of the salt lakes have no surface water and often have a salt crust. Even when dry, however, the lake playas support life, most of which is nocturnal. Iridescent Tiger Beetles and spiders roam the playa at night hunting insects, and Salt Lake Dragon lizards make hunting forays from their burrows on the shore.

Large numbers of aquatic fauna appear after heavy rains filling the lakes and wetlands. While the lake playas are dry, aquatic fauna is 'resting' in the form of cysts in the sediments. These cysts are activated by fresh water and hatch out into clam shrimp, fairy shrimp or brine shrimp larvae as well as the much smaller planktonic fauna such as *Daphnia* and copepods. Within a week or so of the lake filling, predatory insect larvae such as dragonflies, damselflies and various beetles hatch out—their parents having flown in from elsewhere—and hunt the crustaceans. The lake crustaceans complete their life cycles rapidly, since the lakes and wetlands often dry out or become too saline to support life within three weeks of filling. The fauna must therefore hatch, mature and produce eggs or cysts within that time.

In some years with good rain, the aquatic invertebrates reach such large numbers that wading birds such as avocets and stilts arrive en masse and breed on islands in the larger lakes. They have been known to produce two successive clutches of eggs if conditions are favourable and the (mainly) crustacean food source continues.

Salt lake on Mundale Track. Barbara Madden

1

2

1. Alexander Watson
2. Mark Godfrey
3. Alexander Watson
4. Chris Dean
5. Barbara Madden

3

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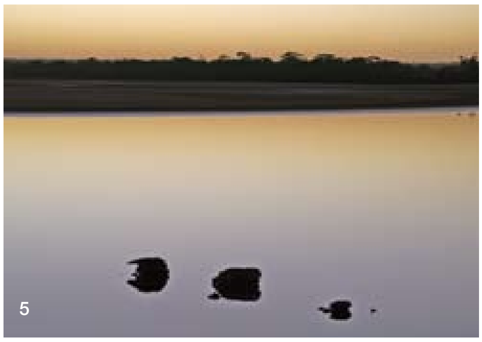


5

The development of a 'Mediterranean' climate (warm, dry summers and cool, wet winters) occurred at the same time as the contraction of rainforests and a radiation of the eucalypts and other characteristically Australian plants (e.g. wattles and banksias). By about three million years ago, Western Australian rainforests were reduced to small remnants, while dry sclerophyll forests and woodlands began to dominate the landscape[26,27]. Deserts formed in central Australia and, eventually, the western rainforests disappeared. No rainforest vertebrates persist today in south-western Australia, though some of the ancient rainforest invertebrates and plants can still be found. Gondwanan rainforest plants are more associated with wetlands and damplands, whereas Gondwanan rainforest invertebrates are found in the wetter forest, in the moist ranges and valleys near the south coast, and in association with granite outcrops[28].

In the last two million years, there have been at least 20 major warm-wet to cold-dry climate fluctuations across the landscape. This shifting climate is one of the most important evolutionary forces shaping the plants and animals now found in the Great Western Woodlands. These major fluctuations in climate meant that the wildlife of south-west Australia was periodically separated from eastern Australia by deserts, then reconnected at a later date. A slight decrease in annual rainfall advanced the desert margin tens or even hundreds of kilometres[18,29]. The most recent expansion of the inland deserts occurred as recently as 7000 years ago[30]. Since then, the south-west has once again become wetter, the deserts have retreated into the interior of the continent, and shrublands, woodlands and mallees have become more dominant.

Conclusion

The Great Western Woodlands today stands largely as it has for millennia—a relatively flat landscape punctuated by breathtaking natural features. For more than 250 million years, the Great Western Woodlands has been a landscape that has seen no mountain building or glacial events, or been covered in oceans. This is an exceptionally long period of time for life to evolve, and has given the landscape a continuous biological heritage that has seen the development of the first flowering plants, the evolution of a complex mosaic of soil types, dinosaurs coming and going, and the appearance of humans.

There have also been large climatic changes. The landscape has slowly dried out in the past 20 million years, and in the past two million years there have been major fluctuations in rainfall. It is the interplay between the age and complexity of the soils, climate, isolation from eastern Australia and many other factors, which have provided the opportunity for a huge amount of speciation to occur. The complex array of vegetation, landforms and soil types results in many different types of habitat for wildlife. As will be outlined in the next chapter, protecting and managing the nature in this region requires us to not only recognise this complexity, but to also understand the key ecological processes that underpin this country.

Every year, species that live in the region survive the hot summers; every century they find a way to cope with long droughts, large fires and even some floods.

CHAPTER 4

04 Key Ecological Processes

To a stranger, the Great Western Woodlands still has a sense of the resilience that has carried it through the millennia. Every year, species that live in the region survive the long summers; every century they find a way to cope with long droughts, large fires and even some floods. However, even in this large, intact landscape, the last century has seen the loss of species at a rate greater than that experienced for at least 250 million years. Australia as a whole has suffered the worst loss of mammal species of any continent, and the woodlands is no exception. The changes we have already seen, and those bearing down on us through global warming and other large pressures, threaten to push the planet into the sixth great wave of extinctions, surpassing the loss of the dinosaurs and other biologically cataclysmic events.

Until now, our piecemeal approach to conserving species and areas has largely failed. Species loss and degradation of ecosystems is, globally and nationally, increasing[1,2,3].

Given this situation, the Wilderness Society funded the formation of a Science Council made up of leaders in the field of conservation biology, landscape ecology and related disciplines. Their inaugural meeting was in May 2000, and they were asked to answer one question:

How can effective conservation systems be designed and implemented so that native flora and fauna persist in perpetuity in Australia?

Since its first meeting, the 'WildCountry Science Council' has maintained that the key to answering this question lies in understanding the role that particular ecological processes have in maintaining species and ecosystems in landscapes [4,5,6,7]. Their research led them to develop a framework based on the recognition that native flora and fauna will have their best chance to survive if ecological processes and environmental drivers are preserved. This framework highlights the importance of large-scale ecological processes, and the landscape linkages needed to maintain the necessary connections, interactions and flows.

The Council's framework also recognizes that the maintenance of such large-scale 'connectivity processes' needs to be integrated into landscape planning and management systems if we are to achieve the long-term conservation of biodiversity across Australia in the coming centuries and millennia.

In this chapter, we describe five ecological processes that are among the most critical for managing and successfully conserving biodiversity across the Great Western Woodlands, notably climate, fire regimes, hydro-ecological processes, plant productivity, and interactive species.

Opposite Image. Vanessa Westcott

Box 4.1 - What is an ecological process?

Dr Barry Traill

The general description I've found best is: *The interactions and connections between living and non living systems, including movements of energy, nutrients and species*[1].
Or in more poetic lay terms: The natural machinery that connects living and non living things and keeps nature healthy.

I won't detail here how ecological processes maintain the natural world we know and love. Suffice to say briefly that these interactions and connections maintain particular tangible assets or values (individual populations, species, ecosystems) in a myriad of ways. When they degrade or are removed or destroyed then tangible things that we want to keep disappear, are degraded, or are reduced in number.

Soule *et al.* 2004 provide a list of seven key types of ecological processes that apply over large distances in terrestrial systems in Australia:

1. Strongly interactive species
2. Hydro-ecology
3. Long-distance biological movement
4. Disturbance regimes
5. Climate change & variability
6. Coastal zone fluxes
7. Maintaining evolutionary processes

The Wild Country Science Council members are, from left Professor Brendan Mackey Professor Harry Recher (no longer a member), Dr John Woinarski, Professor Jann Williams (no longer a member), Professor Richard Hobbs, Dr Rob Lesslie, Professor Hugh Possingham, Professor Henry Nix (co-chair) and Professor Michael Soulé (co-chair). Other members of the Science Council include: Professor Helene Marsh, Dr Trevor Ward, Dr Regina Souter, Dr Joern Fischer, Dr Sarah Legge and Dr Janette Norman.

Barbara Madden.

Climate

Natural climate change has influenced the evolution, distribution and abundance of all Australian species[8]. Therefore, understanding the region's climate — and how it will change in the future — is central to developing an effective conservation strategy for the region[9,10,11].

It is now widely accepted that human-created climate change, caused primarily by the emission of carbon dioxide from deforestation and fossil fuel combustion, is radically changing the earth's climate[12,13]. The speed of these changes poses a special challenge to many species, and produces significant impacts on ecosystems[14,1516]. Although there is debate about what the specific consequences of human-created climate change will mean for Australia's climate, the impacts will not be uniform[9,10]. It is predicted that in the coming decades, the Great Western Woodlands, like most of southern Australia, will be exposed to more frequent extreme weather events, higher average daily temperatures (especially minimum temperatures), and changes in the spatial and seasonal distribution of rainfall[10,17].

It is uncertain how the Great Western Woodlands' biodiversity will respond to these changes. Current models of the predicted impacts are still too broad, and do not take into account the life history strategies of enough individual species[18]. The way life responds to human-induced climate change is likely to vary between species, depending on their inhabited altitude or latitude, their position relative to tolerable extremes, and their ecological versatility[19,20]. Also, the health and intactness of a landscape is critical, as species are expected to respond to the changing climate by moving to track the environmental conditions to which they are adapted[21,22]. One broadly-accepted scenario for the species inhabiting the Great Western Woodlands is that a rapid warming and drying period will progressively favour desert biota, and a south-westward shift of species across the Great Western Woodlands will be the prevailing trend[10].

The size and intactness of the region means that the Great Western Woodlands will likely function as a refugium and a massive connectivity corridor for species threatened by human-forced climate change. It will also likely play a vital role in facilitating natural adaptation responses by species[23]. Irrespective of the specific kinds of climatic changes the region will experience, the Great Western Woodlands appears well placed to function as a critical link between the north-east desert and the wetter south-west areas, and possibly also to the north-west through to Shark Bay .

This connection will become even more significant as the Gondwana Link vision, which plans to reconnect country across south-western Australia, matures and grows (see Box 6.1). With a southwest trend likely in species movement, it is notable that the Great Western Woodlands remains connected, through Ravensthorpe in its southwestern corner, to the large Fitzgerald River National Park. Work is already underway to reconnect the Fitzgerald to the Stirling Range National Park, and planning is in progress for further connections across to the wet karri and tingle forests further west. This will enable mobile species to move across the entire landscape and adapt to changing environmental conditions, and may also facilitate the more gradual movement of plant genes. The fact that the region's ecosystems remain as they have through past climatic fluctuations—across a large block of country covered by a mosaic of different communities—suggests that species there will have greater capacity to adapt and evolve (as presumably they have in the past) to any future climate change.

The Great Western Woodlands' contribution to climate stability

Research at Murdoch University is providing evidence of the interaction between native vegetation and cloud formation in the Great Western Woodlands. This research was conducted along the south-western boundary of the Woodlands, and illustrated the difference in cloud cover above intact vegetation versus cleared vegetation. Above the intact native vegetation (the Great Western Woodlands), there is an increase in cloud formation because of a combination of vegetation surface roughness and dark colour, which together promote convective mixing of the air above. In contrast, the physical changes caused by clearing native vegetation significantly impaired the development of clouds[24,25]. Not only does cloud cover affect evaporation and surface temperatures, but it could also potentially affect rainfall in the region and other key ecological process like plant productivity.

The Great Western Woodlands also plays an important role in the struggle against human-induced climate change through its sequestration of carbon dioxide. During photosynthesis, carbon is removed from the atmosphere and stored in plant biomass. From there, the carbon becomes part of decomposing woody debris and later becomes part of the soil. Vegetation and the surrounding soil therefore act like a carbon sponge as they absorb and store carbon dioxide from the atmosphere (a process known as carbon sequestration)[26]. When native vegetation is cleared, logged or continually burnt, however, much of this carbon is instead returned to the atmosphere as carbon dioxide[27,28]. The actual value of the region as a 'carbon sink' has yet to be calculated, partly because the rates at which the region's woody vegetation grows and dead biomass decays are unknown. However, assuming comparable stocks as other woodlands in southern Australia, the Great Western Woodlands' size and intact state means that its contribution to greenhouse gas mitigation is significant. With appropriate land management, these carbon stocks can potentially provide a substantial source of income, especially if a monetary value is placed on protecting extant carbon stocks in native vegetation. A future research priority must be to investigate the role that these intact ecosystems play in counteracting the impacts of human-induced climate change at regional, continental and global scales.

Clouds over the Great Western Woodlands. There is a strong relationship between intact landscapes and cloud formation. J. Hacker

Fire

The role of fire in Australian landscapes is contentious. Some people believe we are not burning enough, the proof being the catastrophic damage both to the environment and to social infrastucture that results from fires every year. Others argue that we are burning too frequently and at the wrong time of year, resulting in some aspects of biodiversity being threatened by this disturbance, and encouraging ecosystems to become drier and more fire prone. Most ecologists agree that fire has had a major influence on biodiversity across almost all landscapes in Australia, including the Great Western Woodlands[29,30,31,32,33]. Many also recognise that this biodiversity has evolved to exist within one or several fire 'regimes', which consider the pattern of fire events over time in terms of their frequency, intensity and season, and with respect to the area that is burnt[30,31,34].

Many different fire regimes exist across the Great Western Woodlands, reflecting its ecological and geographical variation. For example, some researchers have suggested that fires used to be uncommon in the Great Western Woodlands' woodland and mallee communities, occurring at intervals from 40 to 100 plus years[32,35,36]. In contrast, a much shorter fire interval is thought to have occurred in the shrublands (15–30 years)[37,38,39]. Although there is some research currently being undertaken to assess the 'natural' fire regimes in the woodlands around Lake Johnston[40], much more information is needed to understand the relationship between different fire regimes and biodiversity throughout the landscape.

Vanessa Westcott.

The role of humans in changing fire regimes

Humans have played a key role in altering fire regimes in the Great Western Woodlands. As will be outlined in the next chapter, the region was traditionally inhabited by several Indigenous nations. Very little is known about how Indigenous people used fire in the Great Western Woodlands[36], although it is likely that practices varied between different groups. If we assume that customs in the Great Western Woodlands were similar to those in other areas of Australia (e.g. Central Australia and Arnhem Land in the Northern Territory)[41], these traditional burning practices were probably undertaken in a specific and systematic manner that was deeply considered and embedded within the culture, and ultimately aimed at maintaining food resources [42,43].

Contemporary fire regimes in the region largely reflect either the unintended influence of human activity (e.g. accidental ignition) or burning undertaken to protect life and property[35]. Consequently, they are different from the traditional fire regimes to which many species are adapted. Current fire regimes may therefore threaten biodiversity within the Great Western Woodlands[33]. For example, a preliminary analysis of satellite imagery conducted by the Australian National University shows that approximately 15% of the Great Western Woodlands has been burnt in the five years from May 2000 to May 2005 (Table 4.1). While the precise ecological impacts of the current increased level of fire are unknown, it is suspected that they have already significantly altered the structure and even the composition of many vegetation types across the Great Western Woodlands' landscape. As previously argued, more research is required to understand what kind of fire management is needed to conserve the region's biodiversity as well as the relationship between fire disturbance and other disturbances (e.g. road building, mining, logging)[44]. In the interim, greater effort is needed to prevent the continued occurrence of the extensive wildfires that have taken place in recent years.

Table 4.1

A preliminary summary of the extent of the Great Western Woodlands' main vegetation types burned between May 2000 and May 2005. The analysis was undertaken by examining changes in photosynthesis rates using MODIS data[45,46]

Broad Vegetation Type	Cover (ha)	Area burned (ha)	Proportion burned (%)
Woodland	8 986 723	1 038 229	11.6
Mallee	2 629 419	501 947	19.1
Shrubland	3 219 093	854 453	26.5
Grassland	330 479	128 327	38.8
Unvegetated	813 1898	0	0.0
GWW Total	15 978 905	2 522 954	15.8

Fire is also an important ecological process to consider by those managing carbon stocks and evaluating Australia's contribution to climate change[47]. We believe a consequence of inappropriate fire regimes in regions like the Great Western Woodlands is an increase in Australia's contribution to carbon in our atmosphere. Not only is there an artificially high release of carbon that occurs because of high-intensity, high-frequency fires, but there is also a reduction in the region's ability to store carbon as woodlands are converted to mallee and then shrublands through repeated fire disturbance. As such, managers of fire in the Great Western Woodlands not only need to ensure the ongoing viability of the biodiversity in the region; they also need to ensure that the region remains an important carbon store.

Hydro-ecology

'Hydro-ecology' refers to the relationships between water (both surface and ground water), vegetation, wildlife, and landform at local and regional scales[48]. Since plants need water for photosynthesis, the availability of water determines the rate and amount of biomass produced and thus the height, density and layering of the vegetation. As plants largely access water through their roots, the amount of water available in the substrate is critical. The type of vegetation cover in turn affects water infiltration, the capacity of the soil to hold water, and rates of evapo-transpiration[49,50]. Rainfall recharges soil water, but in climatically arid (or semi-arid) zones such as the Great Western Woodlands, deeply rooted plants can also access ground water to sustain their growth. The vegetation-derived habitat resources used by animals for food, shelter and nesting are also a by-product of hydro-ecological processes. Understanding the hydro-ecological processes of a specific region is an extremely complex task; to date these processes have not been investigated in an integrated way within the region.

Rainfall varies throughout the Great Western Woodlands (Fig. 4.1). As you head east across the region, overall rainfall decreases and the percentage of summer rainfalls increase as cyclones hit the north-west of Australia and travel inland. Average values, however, can be misleading because they do not indicate seasonal and annual variability. There can be many months between large rain events, while at other times there can be regular rainfall for many months. Most of the time the region has very little surface water and relatively dry soil. The fact that there are only a few fresh water sources across the Great Western Woodlands in the summer clearly affects the kinds of species that can persist in the region; those that have survived have developed strategies that enable them to gain the resources they need in a variable environment. For example, mallee roots from a site west of the Woodlands has shown that, to support a two-metre high growth form, some mallees have tap roots over 25 metres deep[51]. Such use of groundwater is likely critical in sustaining plant productivity through the long and variable dry periods in the region. However, plant–groundwater interactions remain a poorly researched phenomenon in the Great Western Woodlands, and need to be further investigated.

1. Vanessa Westcott.
2. Amanda Keesing.
3. Vanessa Westcott.
4. Alexander Watson.

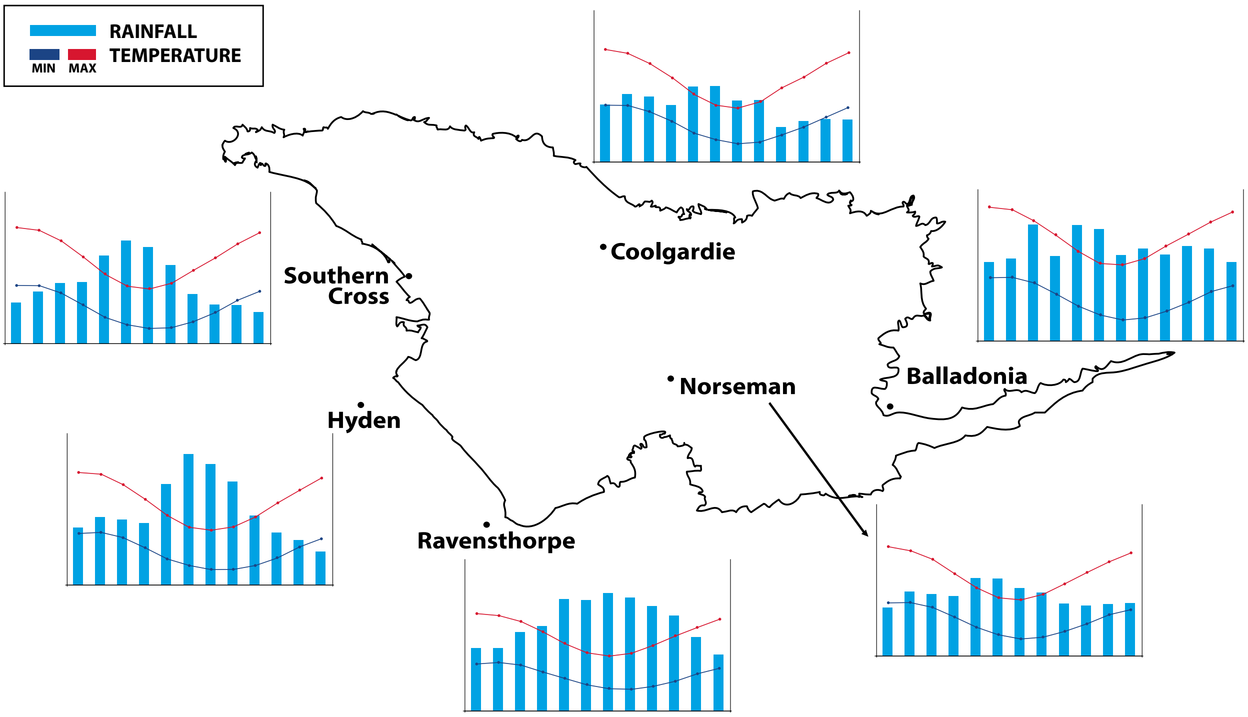


Figure 4.1
Map of the Great Western Woodlands showing the locations of long-term weather stations. Next to each station there is a graph showing mean monthly maximum and minimum temperatures and mean monthly rainfall. Data points plotted extend from January to December. These graphs show that the southwest of GWW has much greater winter rainfall than summer rainfall, whereas rainfall in the northwest of GWW falls irregularly throughout the year.
Data supplied by the Bureau of Meteorology.

Research in the region is also beginning to reveal the variety of strategies that animals have developed in response to the scarcity of water. Some species simply move to the coast or other inland areas of the continent where it has recently rained (e.g., banded stilts). Other species can meet their requirements by drinking nectar (e.g., lorikeets) or burying themselves deep underground only to appear when the next rains come (e.g., burrowing frogs).

Banded Stilts. Amanda Keesing

Despite the fact that very little is known about the hydro-ecology of the Great Western Woodlands, the negative impacts on hydro-ecological processes of inappropriate land use activities in adjacent areas are well documented[52,53,54,55]. Extensive land-clearing and agricultural systems based on annual planting have ensured that 'salinity' is now a household term in Western Australia. Anyone who has travelled through Australia's south-west can see firsthand what happens when the hydro-ecological cycle is altered. It is estimated that Western Australia has 70% of the nation's dryland salinity[56] (Box 4.2). Increased salinity appears likely to have caused the extinction of approximately 450 species of native flora and 250 species of invertebrate water fauna in the Western Australian Wheatbelt[57]. Hydro-ecological processes are critical to maintaining the natural values of the Great Western Woodlands, and their significance demands a substantial investment in ongoing research. If we ignore these ecological relationships, the implications could be dire for the region's biodiversity and contribute to a tumultuous future for future generations that try to live on the land.

Box 4.2 - The salt of the earth: the curse of a landscape out of balance

Professor Richard Hobbs

Where there is a complete cover of native vegetation, most rainfall is captured and used by plants, and very little moves either sideways into watercourses or downwards to the watertable deep below. However, when the native vegetation is replaced by annual crops and pastures, less water is used, more runs off and more penetrates deep into the groundwater. This leads to the groundwater level rising, to the extent that it reaches the surface in some parts of the landscape.

Over much of the Western Australian Wheatbelt, this groundwater is heavily laden with salt that has accumulated there over thousands of years. Salt has always been a natural part of the landscape, and salt lakes and salt-tolerant plants are found in many low-lying areas. However, the rising water tables have brought salt to the surface in parts of the landscape that have never experienced it before, and have also increased salt concentrations in previously saline areas to much higher levels.

Because the plants in these areas are not adapted to these salt levels, and also to the degree of waterlogging that they now experience, many cannot survive. Hence, rising saline water tables are causing the demise of many woodlands and other low-lying vegetation types. Hundreds of plant and animal species which are found only in these areas are now at great risk of local or even total extinction.

Although it is very difficult to predict accurately what will happen, most hydrologists agree that saline water tables will continue to rise as they respond slowly to the massive changes brought about in the landscape. In the worst case scenario, approximately one-third of the Wheatbelt could eventually be affected, with much of the vegetation in the broad valleys succumbing to increased salinity and waterlogging.

Turning this situation around will require a massive effort involving a mixture of broad-scale revegetation and the strategic use of drains and other works. Looking over the Rabbit-Proof Fence to the uncleared vegetation to the east of the Wheatbelt, one has to conclude that the best advice regarding how to prevent the area from suffering a similar fate is to ensure that little or no further clearing of vegetation takes place.

Scientists warned of the dangers posed by salinity caused by clearing at the beginning of the 20th century, and yet clearing in the Wheatbelt not only continued but increased up until the 1970s. Let's hope that similar warnings now do not go unheeded, and that the problems of the Wheatbelt can be avoided in the area beyond the fence.

Dryland salinity. Chris Dean

Geographic and temporal variation of plant productivity

Plant productivity is the rate at which biomass is produced by photosynthesis. It is a key driver of biodiversity because the energy embodied in the new biomass is the basis of all terrestrial food chains. Plant productivity flows through food-webs via interactions along either the 'grazing pathway', which initially starts with herbivores eating plants, or the 'decomposition pathway', involving bacteria, fungi and invertebrates.

Research at the Australian National University has mapped the significant variation in timing and location of plant productivity across the continent. Changes in the availability of water and nutrients, and fluctuations in temperature, significantly alter the productivity of plants within a region[45,46]. For example, droughts and extreme temperatures (high or low) reduce productivity, while short-term productivity is enhanced by events such as rain and recent fire in some vegetation groups. Importantly, research has shown that the Great Western Woodlands has consistently higher plant productivity than most other temperate woodland regions in Australia (Box 4.3). Consequently, we can infer that the region could be significant as a continental refuge because it provides vast and reliable food and other habitat resources for dispersive species that move into the region when times are tough elsewhere[58].

1. Regrowth after fire. Chris Dean
2. Healthy, undisturbed woodland. Barbara Madden
3. Regrowth after logging. Barbara Madden

Box 4.3 - Gross primary productivity — life's fuel supply

Dr Sandy Berry

Gross primary productivity, or GPP, is a measure of the rate at which carbon dioxide, solar energy and water are taken up by green plants during the process of photosynthesis, and converted to carbohydrate, the basic fuel for all life processes.

GPP is affected by the availability of water and nutrients in the soil, the concentration of carbon dioxide in the atmosphere, and the amount of sunlight received. The GPP of natural vegetation, such as that in the Great Western Woodlands, is generally higher than that of nearby land that has been converted to agriculture or pasture. In the case of agriculture, the GPP is reduced because the plant leaves are only present for part of the year and herbaceous crops such as wheat have shallow roots and so are not able to access the water deeper in the soil that is available to trees and shrubs. Similarly, the clearing of woody vegetation reduces the GPP of land used for livestock grazing. The livestock themselves reduce the GPP because their grazing reduces the amount of leaf cover and their hard hooves compact the soil surface, reducing the infiltration of rainfall into the soil and thus the availability of water to plant roots.

Within the Woodlands, the GPP varies with the availability of water and nutrients, and the removal of the vegetation canopy by fire. Within years, the GPP varies with the seasons, while between years it varies mainly with the annual rainfall. Fire causes a sudden reduction in the GPP; following fire it appears to take many decades for the GPP to recover.

Barbara Madden

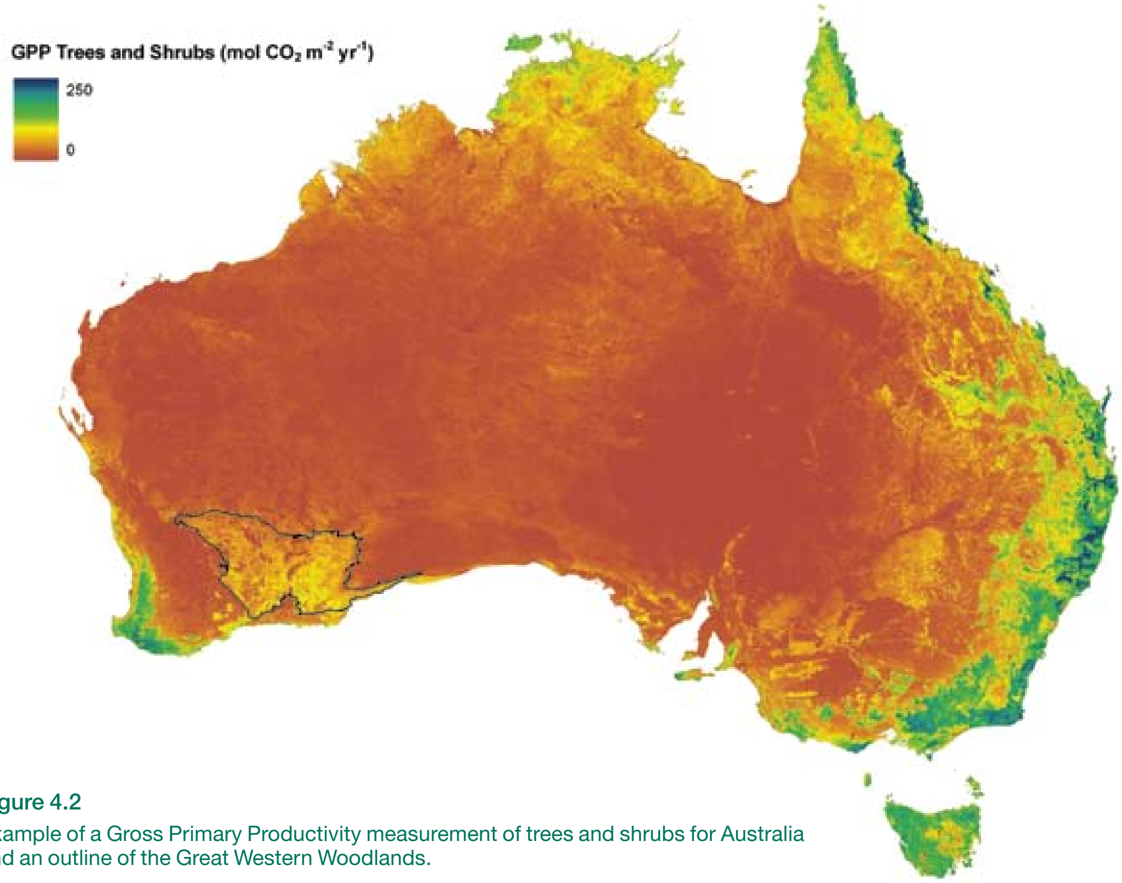


Figure 4.2

Example of a Gross Primary Productivity measurement of trees and shrubs for Australia and an outline of the Great Western Woodlands.

Just as plant productivity varies across the continent, there is significant variation in plant productivity within the Great Western Woodlands. This variation influences the movement of animals across the landscape, and therefore the distributions and abundance of species in a particular spot at a given time[58,59,60]. Animals move into, out of, and around the landscape en masse chasing this productivity. Perhaps the best example of these large-scale movements comes from the region's bird communities. More than 50% of bird species found in the Great Western Woodlands are nomadic or migratory, relying on food resources that vary according to seasonal, yearly and decadal cycles across the Woodlands[58,64]. Rainfall and subsequent plant productivity in a certain area can spur large-scale movements of many species[5,61,62,63]. This movement is not restricted to animals that can fly. There is also temporal variation in reptile[65] and mammal communities[66] across this region.

1

The spatial and temporal variation in primary production across the landscape highlights the need for a 'whole of landscape' management plan for the region. Changed fire regimes, tree clearing, logging, ongoing prospecting, and the development of large-scale mines and associated infrastructure will all have serious impacts on the availability of productive areas of food and habitat resources. They may also impact adversely on other key ecological processes, and combine to have dire consequences for the species that inhabit the region.

The role of strongly interactive species

Some species are particularly important in regulating populations of other species and distributing energy, water, and nutrients within an ecosystem[67]. Identifying these 'strongly interactive species' and maintaining ecologically sustainable populations is necessary to ensure that current biodiversity persists in the Great Western Woodlands[5]. While we do not yet know all of the strongly interactive species in the Great Western Woodlands, we do know that they include:

- major predators (such as dingoes) that control the relative abundance of prey (herbivore) species and competing small predators (including cats and foxes), and in doing so, regulate the rate at which plants are eaten in an area[68,69,70].
- dispersive species (such as honeyeaters, pigeons and emus) critical for the dispersal of fruits, seeds and pollen[71].
- species that change the dynamics or structure of habitats (such as some termites[72,73], which are vital for the formation of the tree hollows used by many other animals, or small mammals, whose foraging habitats can influence soil-water properties)[74,75,76,77].
- species that provide resources for other species, particularly at times when few other resources are available (such as flowering emu bush (*Eremophila* sp.), the fruit of wild cherry *(Exocarpos* sp.*)*, and nuts from sandalwood *(Santalum spicatum)* and quandong *(Santalum acuminatum).*

Changes in populations of these strongly-interactive species are likely to have profound ecological impacts that will percolate through the Great Western Woodlands' web of life. Experience in other ecosystems has shown that mismanagement of populations of strongly interactive species such as these can initiate ecological chain reactions that lead to the simplification, restructuring or disappearance of entire ecosystems[78,79,80]. For example, in the Great Western Woodlands, changing the management practices concerning just one species, the dingo, may have profound repercussions for biodiversity throughout the region. There is anecdotal and some empirical evidence that where there are healthy populations of dingoes there are fewer foxes and cats[81,82] (Box 4.4). It is hypothesized that dingoes compete with cats or foxes through predation and territorial exclusion[70,83]. This is extremely beneficial behaviour when you consider that cats and foxes have contributed significantly to the extinction, and decline, of many Australian animals, including our unique marsupials[84,85,86]. Threatened species may therefore benefit from the continued presence of a strong dingo population in the Great Western Woodlands.

2

1. Migrating Banded Stilts. Amanda Keesing
2. Jewel Beetle. David Knowles

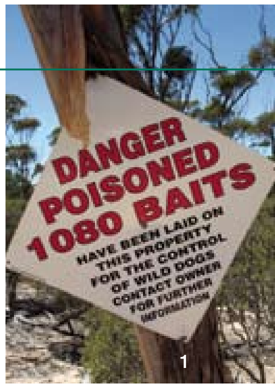
Box 4.4 - Dingo

Professor Chris Dickman

Almost entirely removed from the pastoral lands to the west, and constrained by the aridity of the continental interior and the Nullarbor to the north and east, the dingo retains a stronghold in the Great Western Woodlands. They are usually lean animals with characteristically tawny or ginger coats, and are likely to be purer in the Great Western Woodlands than in most other parts of Australia. Dingoes prefer live prey, particularly large, common species such as emus, red and grey kangaroos, and common wallaroos or euros. Although they may hunt mice and dingoes resort to such morsels only when hungry or when they are abundant and easy to catch. In fact, emerging evidence suggests that small native species derive considerable benefit from the presence of dingoes. As the top predator in Australian ecosystems, dingoes appear to suppress smaller predators such as exotic red foxes and wild house cats, especially in open, timbered areas such as those of the Great Western Woodlands. As the exotic predators have highly destructive effects on small native species of mammals, birds, reptiles and even large invertebrates, suppression of their numbers by dingoes helps to elevate populations of the small prey species, and thus helps to retain significant elements of regional biodiversity.

When dingoes are controlled to reduce their impacts on livestock, the highly structured society of these social predators is disrupted and interbreeding with domestic dogs becomes more likely. Populations of large kangaroos increase, leading in turn to further culling to reduce perceived competition with livestock. Foxes and cats, released from suppression, also increase to destructive levels and deplete native wildlife. For these reasons, scientists have begun to call loudly for more sympathetic approaches to the management of dingoes. It is difficult to imagine that the international community would remain silent in the face of campaigns to exterminate top predators such as lions, tigers and jaguars in other parts of the world. It is a continuous surprise that such campaigns are tolerated against the 'top dog' in Australia.

1. Charles Roche
2. Lochman Transparencies



The management of Dingo populations in the Great Western Woodlands is complicated because there are now also large populations of 'wild dogs' in the region. These dogs comprise escaped pets and farm dogs that now live in the bush. They interbreed with dingoes, and there has been concerted attempts to reduce their populations in the region.

Although dingoes have been regularly poisoned and trapped, they do continue to exist in the region. Research on dingo-cat/fox interactions and a review of dingo population management is now urgently required. If current theory is correct, letting dingo populations recover to a healthy number may be the precondition needed to re-introduce marsupial species that have gone extinct in the region but exist elsewhere.

It is clear that more research is needed in the Great Western Woodlands to identify the role of dingoes as ecological regulators, and to identify other key 'strongly-interactive' species, along with their habitat requirements. The identification and maintenance of these species on a landscape-wide basis is an important component that needs to be embedded in the management of the region.

Conclusion

This chapter has highlighted some of the ecological processes that are essential in maintaining the integrity of the Great Western Woodlands. These enhance 'connectivity', or ecological permeability, between ecosystems and species and ensure that the landscape functions effectively. In effect, they drive ecosystems by shaping all components of biodiversity in the Great Western Woodlands—genes, species and other ecological processes.

The processes described in this chapter are not a definitive list of all key ecological processes that occur in the Great Western Woodlands. Identifying and understanding other key ecosystem processes should be of the highest priority for research scientists in the region. Subsequently, regional managers must understand and implement strategies that ensure that these processes continue to operate in ways that benefit, not erode, nature. If any of these drivers are ignored, altered, degraded or destroyed, significant components of the region's biodiversity are likely to disappear forever.

The story of the Great Western Woodlands… is a history of human survival, and often prosperity, in a landscape that challenges even the most resourceful of people.

CHAPTER 5

05 The people in the landscape

The story of the Great Western Woodlands and its surrounding towns tells the history, on a small scale, of Western Australia itself. This is a history of human survival, and often prosperity, in a landscape that challenges even the most resourceful of people. It is a story of extremes where ingenuity and sheer determination gave rise to legendary human achievements—where the personalities are almost as large as the projects they made possible. From Indigenous ways of life that survived tens of thousands of years, to the colossal scale of the Kalgoorlie gold rushes, to engineering feats that pipe water 600km inland from the coast and built a 3200km fence designed to repel invading rabbits, this region has been the stuff of both modern day and ancient mythology. Despite this, however, the Woodlands' natural elements ultimately control human activity in the region, and its weathered soils and aridity have conspired with economic fluctuations to resist broad-scale development. Today, the Great Western Woodlands remains predominantly 'unallocated crown land', and therefore awaits an uncertain future.

Indigenous ownership and management

After millennia of occupation and social development, Australia at 'the threshold of colonisation'[1] was the home country of more than 300 Aboriginal language groups, comprising thousands of homeland estates. These homelands and their internal governance provide the basis for contemporary claims to native title.

The homelands were the foundation of a continental-scale, regionally distinct, social and economic life. Country was maintained in accordance with specific laws and customary management, creating a 'cultural landscape'. This varied between groups and with the type of country in which their homelands were situated, with distinct geographic and climatic variations evolving across the continent. These homelands have been the primary unit of landscape management in Australia for millennia, with Aboriginal Traditional Owners the primary landscape managers.

It is thought by archaeologists that the earliest permanent occupation of Australia's inland arid regions occurred at least 22,000 years ago. Over time, population shifts and even possible hiatuses are likely to have occurred in response to changing conditions. Extreme aridity during the last glacial maximum approximately 18,000 years ago, for example, would have limited the capacity for people to survive in the desert regions, and resulted in decreased population density and the abandonment of some sites and corridor areas.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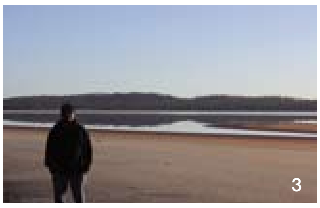
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Image opposite. Joanna Jones
1. Gnamma holes. Amanda Keesing
2. Joanna Jones
3. Ngadju representatives. Alexander Watson
4. Ngadju representatives. Alexander Watson
5. Alexander Watson

The continuities and discontinuities in Indigenous presence do not negate Aboriginal people's persistent ownership, cultural inscribing of the landscape, or adaptive learning. Archaeological evidence shows a direct and continuous Aboriginal role in the maintenance and use of locations and resources in the region for many thousands of years.

Over such a long time scale, the use and management of the area by its Traditional Owners had a direct influence on many of the characteristics of the environment we see today. Although we cannot be sure of details, there can be little doubt that, at times, particular types of vegetation were favoured or reduced in an area by management decisions such as where, when and how to burn. Similarly, fauna populations would have responded in varying ways to fire regimes, hunting pressures and other practices.

Adapting to life in such dry country required detailed knowledge of the distribution and seasonality of a wide range of foods, as well as of various processing methods. Also of critical importance was the technical ability to construct and maintain deep wells to either tap or capture water[2], and extended kinship and social networks to sustain and expand occupation and use.

Traditional Aboriginal land use relies on intricate ecological and geographic knowledge. Over thousands of years, an intimate cultural understanding of the landscape and biota grew as successive generations watched seasons change and developed a 'cultural map' of their homelands. This knowledge is encoded in laws, stories, song, language, art and ritual, and has been passed through countless generations of custodians.

Changes wrought from the time of European settlement have created massive social, cultural and economic upheaval for the Aboriginal people. In the Woodlands, as elsewhere, traditional patterns of occupation, land and resource management, and the scale and nature of human influence on the landscape were dramatically altered as Indigenous people were forcibly removed from country. Yet knowledge of and connections to country by the Traditional Owners remain. These ties continue today, with Traditional Owner connections to the entire Woodlands. Presently there are 18 native title groups with claims in the area covering more than 95% of the landscape.

We believe that safeguarding the integrity of these customary connections is vital to the protection, maintenance and evolution of any land or seascape. Historians and scientists have not yet paid enough attention to a range of customary Indigenous practices that are likely to be critical in successfully maintaining the full diversity of natural values found in the region. The long-accumulated ecological knowledge that underpins these practices is an important touchstone in understanding country.

Exercising and adapting these traditional practices to contemporary conservation and land management requires a direct management role for Traditional Owners. From the perspective of conservation science, traditional Indigenous management can be a vital part of responding to environmental challenges. Moreover, the utilisation of the latest conservation science, as well as contemporary techniques for recording and transmitting knowledge, can be a vital adaptive strategy for Indigenous custodians. Together, we can help respond to new and emerging threats.


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1. Ngadju representatives. Joanna Jones
2. Ngadju representatives. David Mackenzie
3. Ngadju representatives. Phil Drayson

Explorers and prospectors in a dry land

Dutch explorers were the first Europeans to record the ancient landscapes of southwestern Australia, from the deck of vessels blown off course as they sailed between Europe and Java. The first detailed mapping of the southern coastline was by Frans Thyssen on the 't Gulden Zeepaerdt in 1627[3], who named the area Nuytsland in honour of a Dutch East India Company official. It was another 164 years before the next recorded visit, when British Commander George Vancouver took possession of the south-west corner of 'New Holland' for Great Britain[3]. The French followed in 1792, landing ashore near Esperance with their ships L'Esperance and Recherche, followed by the discovery and mapping expedition of explorer Matthew Flinders in 1802[3].

These explorers were followed by sealers, whalers and then settlers, but they all clung to the coast, and for good reason…

> *"Shall go for the granite. Camped in scrub, nearly all done. Three days and now three nights, not a drop of water, no damper. Horses nearly all done. My poor little dog I fear will die. Have the camels tied down and horses tied up. No rain here for months. Oh, what a damnable country. If we do not get water tomorrow we will all be done. We are all in a terrible state for water."*
>
> Approaching Johnson Lakes from the south — from the diary of Frank Hugh Hann, explorer, 8 September 1901.[4]

Striking out into the great unknown—the parched interior of Western Australia—was a dangerous undertaking for recently-arrived Europeans. In 1848, Lieutenant Roe, Western Australia's first Surveyor-General, traversed the country around Lake Cronin, which sits near the edge of the Great Western Woodlands. Although he was disappointed with the areas prospects for agriculture, it did not deter several expeditions in the 1860s from exploring the land around Southern Cross and Coolgardie to assess it for pastoralism. Exploration by CD Hunt in this vicinity led to 'Hunts Track' being cut in 1865, providing an access route to the region from Perth that ran roughly along today's Great Eastern Highway[5].

1. Watson's camp, Rabbit Proof Fence. Battye Library (001923D)
2. Associated Gold Mine (Kalgoorlie, W.A.). Battye Library (011186D)
3. Disused gold mine. Battye Library (021965PD)

From the 'roaring 90s' to the present day

The discovery of gold at Southern Cross[5] in 1888, Coolgardie[6] and Dundas[7] (near Norseman) in 1892, and Kalgoorlie[8] in 1893 triggered a mining boom that transformed the land and had a radical impact on its population. Within a decade, the region's population had exploded to 50 000 people, the world's longest water pipeline had been constructed, hundreds of mining companies had been floated on the London Stock Exchange, and over 50 towns had emerged around the goldfields[9]. Many of these diggings were short-lived and had been abandoned within the decade, leaving ghost towns and mine workings overgrown with vegetation. Some who had come from overseas or escaped eastern Australia's depression of the 1890s found wealth and prosperity. But many did not, instead suffering hardship, sickness, or death from poor supplies and harsh working conditions[6].

In these early days, most visitors to the Woodlands either worked in the mines themselves or in one of the many related service industries. One such group was the 'woodliners', mostly migrant workers who supplied mines and towns with the enormous quantities of wood needed for power generation (e.g. steam trains and water-pumping stations) and for the wooden beams needed to support tunnels in the many underground mines[10]. Radiating outwards from Coolgardie, up to 500 workers at a time constructed and utilised a vast web of train lines to transport up to 1200 tonnes a day of Salmon Gum, Gimlet, Merit, Boongul, Blackbutt and other trees to the furnaces and mine shafts of the Goldfields[11]. Known as the Woodlines, this railway network's 65-year working life was instrumental in shaping the Western Australia we know today (Box 5.1). It is estimated that as much as 30 million tonnes of wood was removed along these woodlines from approximately four million hectares of woodland[10].

Box 5.1 - End of the line?

Bill Bunbury

The Woodlines comprised Australia's largest bush railway network, stretching in every direction in the southern Goldfields (Fig. 5.1). Originally set up in the early 1900s, the woodlines would bring almost two million tonnes of hardwood timber into the new and rapidly growing Golden Mile in Kalgoorlie. Its use? Roasting gold ore to extract the precious metal, and becoming pit props for mines and firewood for domestic use, needs sustained until the mid-1960s.

Today we'd question this exploitation of the natural environment, and opinion is still divided over the long-term impact this logging had on the natural environment. But the story of the Woodlines is also about human inhabitation—however temporary—and the attitudes and values that the Woodlines helped to shape. Life on the move, for example, replaced traditional static village life as the men constantly moved location to cut out the timber.

"Moving camp or shifting as we used to call it, is vivid in my memory because all the huts had to go on to the railway wagons to be moved and, with the families, whoever moved first, the family staying behind would cook their breakfast on the morning they left."

[Bondi Olga, interview with Bill Bunbury for the book ***Timber For Gold***[11]*, Broadcast Hindsight ABC Radio National]*

The Woodlines' story ended in 1964 when the mines began to use other sources of power, but the impact of woodland clearing remains an important environmental question. Increased rainfall in recent years has hastened regrowth, but it is probably too early to know yet whether the region's original biodiversity has survived such a massive, if unintended, ecological experiment.

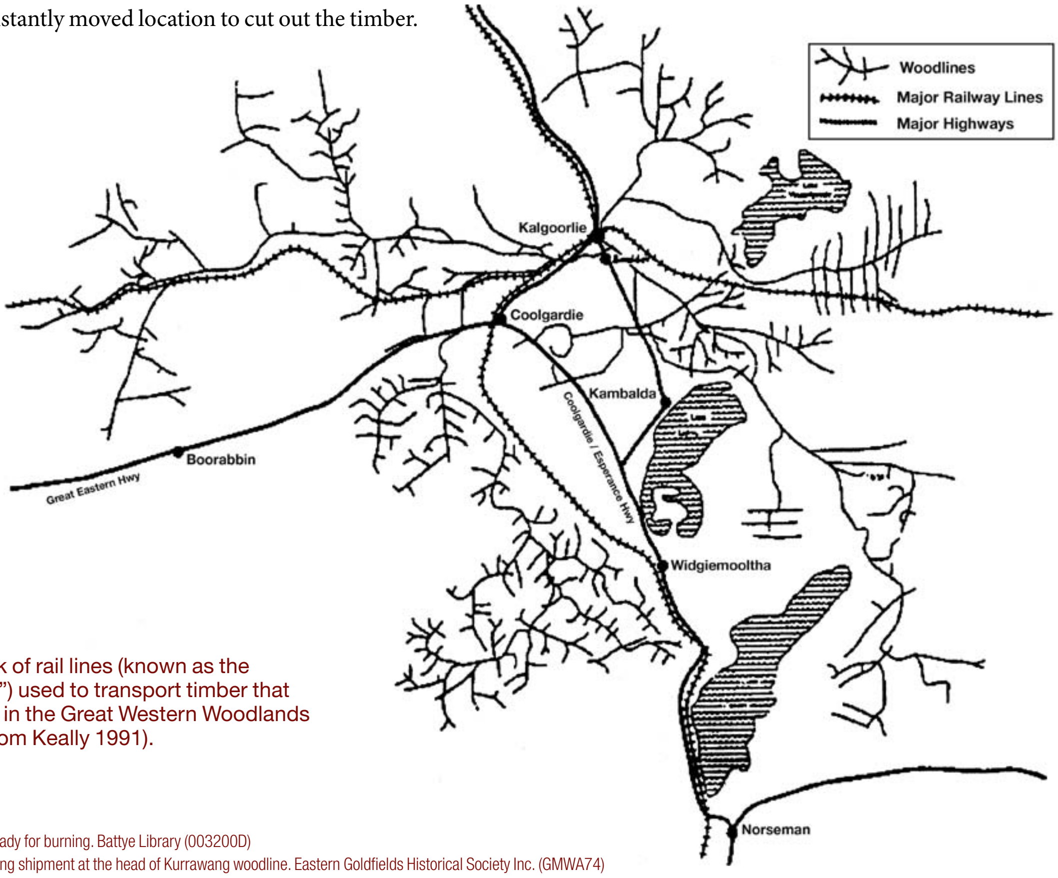

Figure 5.1

The network of rail lines (known as the "Woodlines") used to transport timber that was logged in the Great Western Woodlands (modified from Keally 1991).

1. Felled timber ready for burning. Battye Library (003200D)
2. Firewood awaiting shipment at the head of Kurrawang woodline. Eastern Goldfields Historical Society Inc. (GMWA74)

The meteoric growth of both economy and population in the 'roaring 90s' also saw a proliferation of banks, breweries, churches, stores, newspapers, houses and infrastructure [6,7]. Further mineral discoveries throughout the 20th century, such as the discovery of nickel in the 1960s, continued this growth. So too did the 'opening up' of land for agriculture and pastoralism, with agricultural research stations established at two locations in the Woodlands—Forrestania and Ninety Mile Tank—and farm survey track extended far into the Woodlands southern portion. For a variety of reasons, however, from the availability of other land to dropping wheat prices at critical junctures, most agricultural expansion by the 1970s remained stopped at the southern and western boundaries of the Great Western Woodlands (see Box 1.2).

By the 1980s, the Wheatbelt's worsening salinity problem and a related rise in environmental awareness began creating an ethos of 'land care'. Bleak economic predictions for 'marginal' agricultural land combined with public pressure to convince the government to defer any plans for agricultural expansion east of the Rabbit-Proof Fence[12].

1. Amanda Keesing
2. Barbara Madden
3. Barbara Madden
4. Amanda Keesing


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Box 5.2 - The Rabbit-Proof Fence

Dr Alexander Watson and Keith Bradby

Mention the Rabbit-Proof Fence, and most people think of the 2002 movie that relived the account of three Indigenous girls who followed the fence to return home after fleeing a settlement near Moore River in the 1930s.

The Rabbit-Proof Fence, however, also represents Western Australia's desperate attempt to stop a plague of rabbits from invading the south-west of the state—a pioneering, if ultimately unsuccessful, venture into what we now call biosecurity. Only 30 years after rabbits were introduced for sport in Victoria in 1859, rabbits crossed the Nullarbor Plain and started to colonise the eastern side of Western Australia. The government acted almost immediately, building what was then the longest fence on Earth (3256 km) in an attempt to stop the pest's spread (Fence No 1) (Fig. 5.2). Unfortunately, rabbits breached the barricade before it was finished, and two more fences were ordered (Fig. 5.2). Fence No 2 begun in 1905, and the third fence was completed in 1908. These barricades successfully kept rabbits out until the 1920s, when the boundary was again breached. It is only since the introduction of the disease Myxomatosis in the 1950s that rabbit populations have been controlled.

For much of its southern length, No 1 Fence delineates the sharp boundary between the Woodlands and the Wheatbelt. The Fence is still maintained by the state government today, no longer against invasive rabbits, but, in a bizarre twist, against the movement of native animals such as emus and dingoes. When dry seasons hit the Woodlands, these and other animals move toward the fence in an attempt to reach the wetter country to the southwest. Emus, for example, move along the fence in numbers reaching the tens of thousands, generally being shot along the way or when they end up on farms at the Fence's southern end.

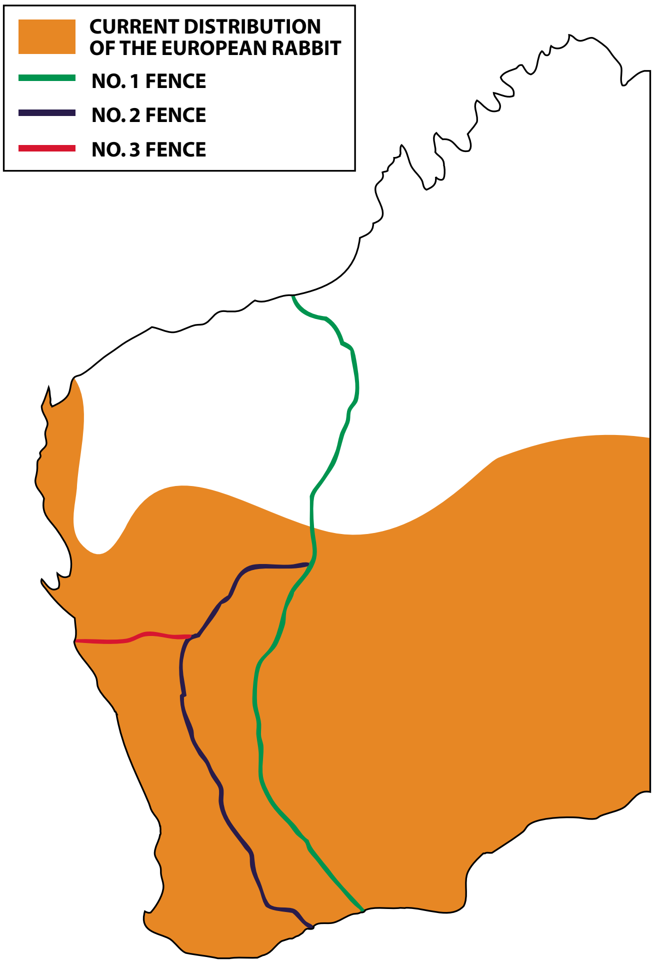


Figure 5.2
The distribution of rabbits and the three 'Rabbit-Proof Fences' in Western Australia.

1. Charles Roche
2. Alexander Watson

Today, it is estimated that 50 000 people live in the Great Western Woodlands' major towns of Kalgoorlie, Coolgardie, Norseman and Southern Cross. Mining, mineral exploration and associated activities remain the primary commercial drivers. Under current production, the extended Kalgoorlie mining province represents more than 50% of the state's gold resources, and 80% of its nickel resources. Overall, Department of Industry and Resources figures from 2007[13] shows this region produces 17% of the economic wealth generated by minerals and petroleum in Western Australia. These activities are concentrated along three main greenstone geological formations—one in the west, one centrally located, and one upon which Norseman and Coolgardie rest in the east (see Fig. 3.2 page 29).

Tourism within and around the Great Western Woodlands—and increasingly nature-based tourism—has recently grown to also make a significant contribution to local economies. Following international trends in the growth of tourism, independent travellers wanting to experience 'outback' camping, four-wheel adventures and bird watching are increasingly drawn to the region. This has been helped by the re-creation of the legendary Holland Track (Box 5.3) by four-wheel drive enthusiasts in 1992 [14], and the recent provision of basic tourist and interpretive signage along the Hyden to Norseman Road.

Box 5.3 - John Holland and his track

Jesse Brampton

In September 1892, prospectors Bayley and Ford announced to the world that they had 'struck it rich' at a place called Fly Flat, just outside of Coolgardie. News of their extraordinary find spread around the world like wildfire, and soon gold seekers were pouring into Western Australia from all directions.

Many came from the eastern states and landed at the port of Albany. From there they took a train north to York or Northam before setting out on the arduous trek east to the diggings. Clearly a short cut to the new goldfields from a town further south on the railway line would be advantageous for both the prospectors and the town, which could then capture the lucrative business of supplying the would-be miners.

Several parties set out from Katanning or Broomehill but were turned back by what appeared to be a harsh and waterless landscape. Then John Holland, an experienced bushman engaged in sandalwood carting and kangaroo shooting in the Broomehill district, took up the challenge.

With his party of Rudolph and David Krakouer, John Carmody, and five ponies with a light dray, he set out from Broomehill in April 1893. Just two months and four days later they reached Coolgardie, having not only blazed a trail but having cleared a functional cart track as well. Almost immediately, the track was being used by hundreds of eager diggers, travelling on horseback, in camel teams carrying supplies, on bicycles, or on foot, pushing wheelbarrows.

The 500 kilometre route between Broomehill and Gnarlbine Rock south-west of Coolgardie was claimed at the time to be the longest cart track ever cut in one stretch in Western Australia. Unfortunately for those who had backed Holland's audacious mission, however, the Track proved short-lived. The extension of the eastern railway from Northam to Coolgardie just three years later effectively put an end to its use.

Today the original Holland Track serves as a four-wheel drive 'adventure' route, but the "John Holland Way" is a more easily traversed gravel road following a similar route from Broomehill to Coolgardie. You too can follow the wheel ruts of this remarkable bushman if you visit the Great Western Woodlands.

Research information courtesy of Westate Publishers' "Explore the Holland Track" Granite and Woodlands Discovery Trail — Site 3: Panel 1

John Holland.

Table 5.1
Current land tenure in the Great Western Woodlands (GWW).

Land Tenure	Hectares	GWW land area
'A' Class reserves	570 830	3.6 %
'B' Class reserves	784 407	4.9 %
'C' Class reserves	717 320	4.5 %
Unallocated crown land (UCL)	9 769 361	61.1 %
Pastoral Leases (including Indigenous-held leases)	3 265 976	20.4 %
UCL Ex Pastoral managed by DEC	317 673	2.0 %
Other crown reserves	385 352	2.4 %
Private land	Data not obtained	~ 1 %

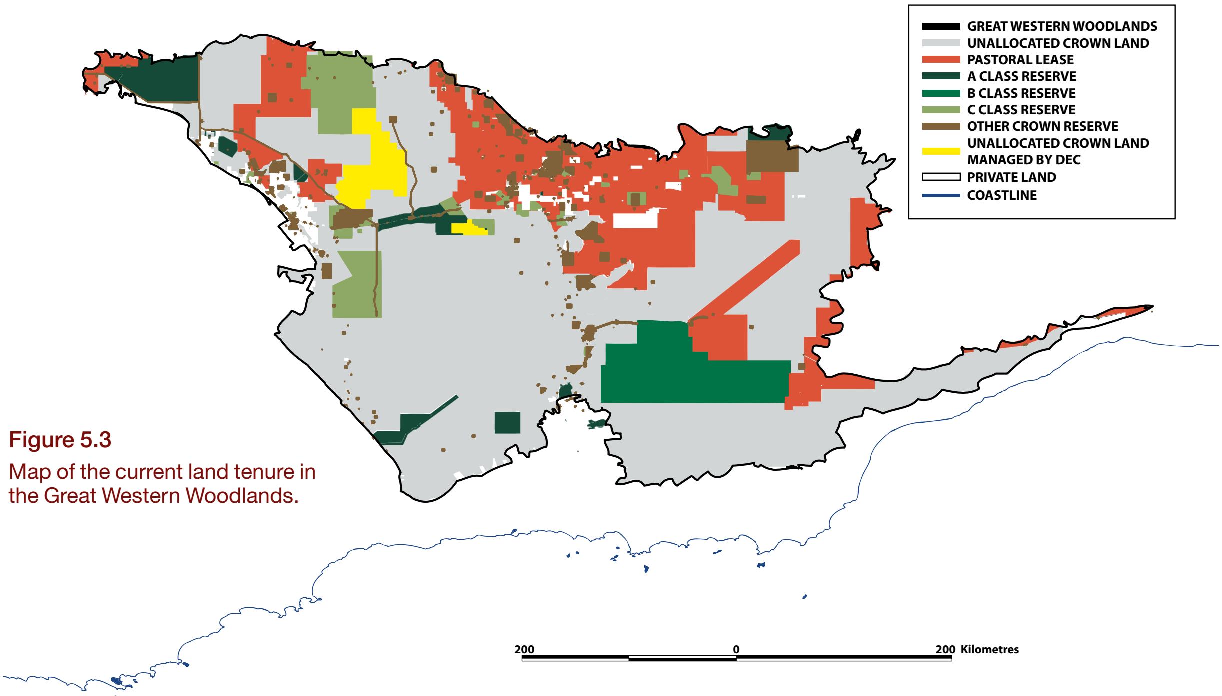


Figure 5.3
Map of the current land tenure in the Great Western Woodlands.

Land tenure, land use and land management

Currently, the dominant land tenure in the Great Western Woodlands is Unallocated Crown Land (UCL), comprising 60% of the total area. The other major land tenure is crown land pastoral lease (20 %). Conservation reserves (national parks, nature reserves, and conservation parks) account for 17%, with 3.6% being Class 'A' reserves, 4.9% Class 'B' and 4.5 % Class 'C'. The 'A', 'B' and 'C' classification effectively refers to the level of security of the reserve, with 'A' Class reserves requiring Parliamentary approval for change or cancellation, while 'B' and 'C' Class reserves have little security of tenure or purpose. The remainder of the land area is divided between Shire reserves, other Crown reserves, freehold land (2%) and UCL managed for conservation by the Western Australian Department of Environment and Conservation (DEC) (2%) (Table 5.1; Fig. 5.3). Approximately 99% of the total area is also subject to native title claim and is currently before the relevant determination bodies[15].

The current responsibility for managing more than 13 of the 16 million hectares comprising the Great Western Woodlands lies with the Western Australian Department of Environment and Conservation (DEC). This department is not only responsible for managing the area's conservation reserves, but is also responsible for managing the UCL in this region. It is clear that government funding does not provide DEC sufficient resources to appropriately manage these lands.

With respect to areas that are primarily allocated for biodiversity conservation, the largest reserves are the "C" Class Dundas Nature Reserve (784 407 ha; 4.8% of the GWW) and Jilbadji Nature Reserve (207 293 ha; 1.2% of GWW). Jilbadji was gazetted in 1954 to preserve plants thought to occur nowhere else, including *Eucalyptus steedmanii* and *Banksia audax*. The smaller Peak Charles National Park (39 952ha; 0.2% of GWW) encompasses the Great Western Woodlands' highest peak. Frank Hann National Park, at 69 086 ha (0.4% of GWW) is the largest "A" Class reserve in the Great Western Woodlands. While of reduced conservation value, due to its elongated shape following a road, it celebrates through its name the remarkable endurance of one of the Woodlands' first European explorers, and provides a long reserve of protected land. The Woodlands also contains 28 620 ha of former pastoral land managed for conservation. This is called the Goldfields Woodlands Management Area, and adjoins both the Goldfields Woodlands National Park and the Goldfields Woodlands Conservation Park.

There are also three existing proposals for new nature reserves in the western part of the Great Western Woodlands. These are proposed for the Mount Day area to the north-west of Lake Johnston, Knapp Rock (to the north of Lake Johnston), and a portion of the Bremer Range between Lakes Hope and Johnston. All three areas are currently unallocated crown land. The Goldfields Woodland National Park is also proposed to be extended by 142 140 hectares[16].

As an area still largely in its natural condition, the Great Western Woodlands' direct economic contribution to state and regional economies is unclear. The Great Western Woodlands is so large that it spans 12 different shire council areas, whose major economic sectors are mining, agriculture, pastoralism and tourism (Fig. 5.4). Other economic activities within the Great Western Woodlands include the management of conservation reserves, beekeeping, seed collecting, and the construction of roads and other infrastructure for shires and mining companies.

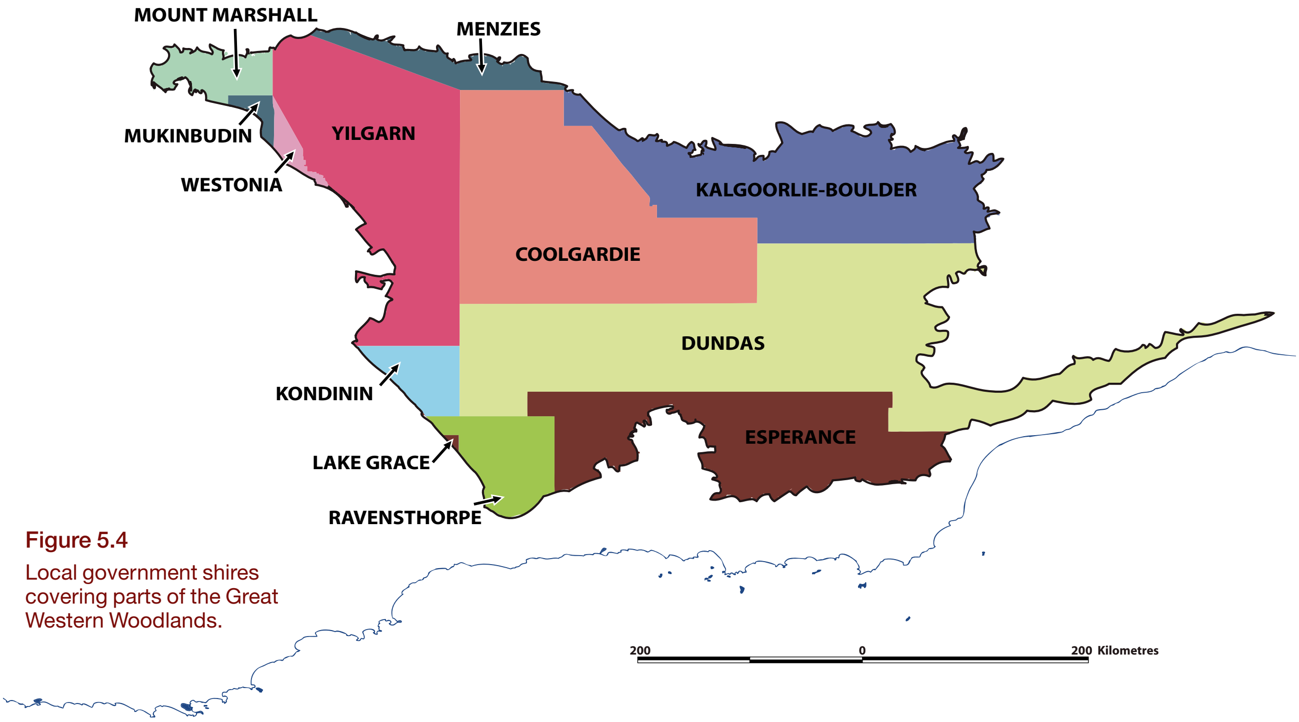
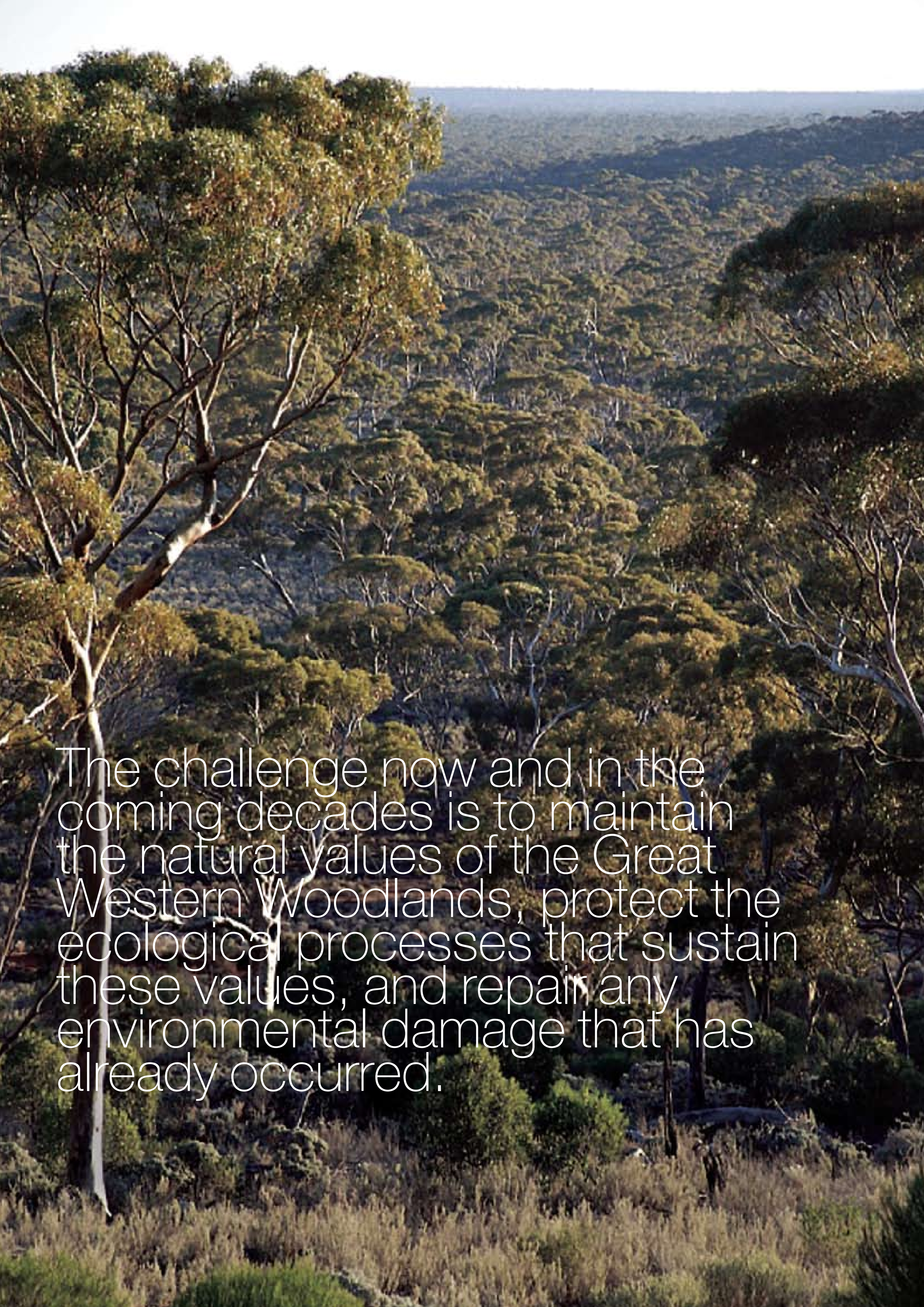


Figure 5.4
Local government shires covering parts of the Great Western Woodlands.

Conclusion

Since first settlement by Europeans 100–150 years ago, the population and land use of the Great Western Woodlands has changed in many ways. One of the most distinct changes is in the distribution of people. In the early 19th century, Indigenous people were dispersed throughout the Woodlands, taking advantage of seasonal resources and playing an important role in the ongoing management of the land and its wildlife. Since the influx of miners, pastoralists, loggers and farmers to southern Western Australia in the late 1800s, however, the pattern has been for both Indigenous and non-Indigenous people to become concentrated in population centres. There are approximately 40,000 people currently living in the shires around the Great Western Woodlands, with the majority of these residing in main towns.

One of the most striking facts regarding our relationship with the Great Western Woodlands is that fewer people now live on-country and actively manage the region than at any time since its permanent settlement thousands of years ago. The question now is how we can effectively manage the natural values of this place with so few human custodians.



The challenge now and in the coming decades is to maintain the natural values of the Great Western Woodlands, protect the ecological processes that sustain these values, and repair any environmental damage that has already occurred.

CHAPTER 6

06 A sustainable future for the Great Western Woodlands

The Great Western Woodlands is one of the largest and healthiest natural landscapes on Earth. If you travelled to the Mediterranean, or to temperate areas in North and South America, Asia, Africa or Europe, you would not find any other ecosystem mosaics which are as large or as intact.

The Great Western Woodlands provides a unique opportunity to learn, as it is one of the last reference points for scientists to understand the ecological processes at work in natural systems. It allows scientists to study how species respond to climate change in an intact landscape, and to gain further understanding of the role that functioning woodlands play in sequestering and storing carbon from the atmosphere.

Yet all is not well in the Great Western Woodlands. Threats to the region's biodiversity include significant increases in large, intense fires; climate change; fragmentation and loss of critical habitat; weeds and feral animals. The challenge now and in the coming decades is to maintain the natural values of the Great Western Woodlands, protect the ecological processes that sustain these values, and repair any environmental damage that has already occurred. If we fail in this challenge, then it is inevitable that much of this unique landscape will be lost. We will also lose a unique opportunity to prevent the kinds of environmental problems now dominating most of southern Australia—water security, species extinctions and land degradation[1,2].

In this chapter we argue that conventional conservation-planning methodology will not work in the Great Western Woodlands. We therefore outline an alternative approach to landscape management that depends on collaboration among the organisations, communities, governments and individuals with responsibilities for land stewardship in the region. We show that this type of approach to management does not mean the exclusion of humans from a landscape. However, managing modern, industrial activities will be critical if the Great Western Woodlands is to remain a legacy for future.

Opposite image. Chris Dean
1. Pipelines. Charles Roche
2. Introduced donkeys are wreaking havoc. Charles Roche
3. Dust coming off a road train on the Hyden Norseman road. Barbara Madden
4. Exploration for minerals. Barbara Madden
5. Vehicle damage on salt lake. Alexander Watson

Protecting the natural legacy

Historically, the environmental values of the Great Western Woodlands have been generally discounted, and the environmental impacts of economic activities in the area largely overlooked. The rationale occasionally put forward has been that with so much bush, there is simply no need to be concerned. More recently, it has become mandatory to assess the local environmental impact of site-specific projects such as mining. However, the process ignores any cumulative environmental impacts associated with these projects. Similarly, the widespread and pervasive impacts from activities such as road building are often not adequately considered. Instead, it is assumed that there is abundant land 'somewhere else' to cater for natural values.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These are symptoms of an *ad hoc* approach to land use and planning, with a narrow focus on acute, site-specific development pressures. We argue that this is not strategic, and will result in the incremental erosion of the region's outstanding biodiversity and natural values. We propose instead that a sustainable future for the Great Western Woodlands can be achieved only through broad-scale and long-term visionary planning, under which primacy is given to the national and international significance of the natural landscape.

Managing the landscape

The ecological processes that sustain the natural values of the Great Western Woodlands will not be protected by conventional conservation planning. A new approach to land management and land use, however, has been developed in sparsely-populated and largely-natural landscapes in North America[3], and subsequently adapted for Australian conditions[4,5]. This approach recognises that conservation can only be successful when it occurs across all land tenures and when different stakeholders work together with biodiversity conservation in mind (Box 6.1; Box 6.2). The central component of this approach is to identify and conserve the key large-scale, long-term ecological processes and interactions that drive and enhance 'connectivity' between ecosystems and species and thus maintain biodiversity at all scales [4,6] (see Chapter 4). To guide this approach, five guiding principles for intact landscapes have been proposed[7]:

1. The natural environments must be valued, with recognition of their national and international significance.
2. The ecological integrity of the processes that support life must be maintained.
3. The population viability and ecological effectiveness of all native species must be maintained.
4. Thresholds defined by the limits of ecological integrity, including cumulative impacts, must be used to assess and guide economic development options.
5. The contributions of Traditional Owners, property holders and managers deserve respect in their own right and are needed to maintain the area's natural values.

An important feature of this new approach to managing landscape is the theme of 'unifying and linking' protected areas, and not automatically excluding degraded lands, or degrading human activities, from conservation initiatives.

1. Chris Dean
2. Charles Roche
3. Mark Godfrey
4. Mark Godfrey

Box 6.1 - Gondwana Link—new processes in ancient landscapes

Dr Simon Judd

Southwestern Australia is renowned for its ecological diversity. Hundreds of millions of years of evolution across one of the earth's oldest land surfaces has shaped an internationally significant 'biodiversity hotspot'. However, extensive clearing of vegetation for agriculture has fragmented an amazing biota. Human-forced climate change and the effects of fragmentation now threaten the long-term viability of much of this extraordinary landscape. Across south-western Australia, rarity is commonplace and the common are becoming rarer.

Gondwana Link is a private sector response to this ecological crisis. Its vision is to protect, connect and restore critical elements of ecosystem function, from the karri forests of Australia's south-west corner to the woodlands and mallee bordering the Nullarbor Plain. This is a highly significant intact natural area made up of a series of biologically rich and complex ecological mosaics containing some of the world's most ancient habitats. The aim of our work is to provide enough connected habitat to allow the native plants and animals both to survive in the short term and to continue to evolve long into the future. The Great Western Woodlands forms the eastern end of Gondwana Link.

The current cooperative effort involves seven organisations and a range of individuals. Collectively, they bring together a wide spectrum of conservation strategies, including public advocacy, land purchase, ecological restoration, public education, property covenanting, and the provision of incentives and expertise for conservation on private land. By working collectively, each group's conservation efforts are complementary—resulting in the pooling of resources, joint strategies, and synergy. As well as building on each group's strengths, this integrated approach minimises duplication and maximises flexibility.

Our approach to conservation transgresses the traditional approach where conservation solely depends on a system of reserves. Gondwana Link is not intending to design and implement a blueprint for conservation in south-western Australia. It is about an ever-evolving conservation change process built on personal, community and organisational connectivity. Our philosophy is to maximise both the opportunity to do great conservation work, and the positive ecological impact of the things we do. We hope that the work of achieving Gondwana Link will be infectious. The more we do, the more people and communities connect with our vision. In this way, connectivity builds connectivity.

1. Planting trees. Amanda Keesing
2. A typical Gondwana Link landscape. Photographer unknown
3. Seedlings for planting. Amanda Keesing


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Box 6.2 - Why a conventional target-based approach to conservation planning will not work in the Great Western Woodlands

Dr Barry Traill & Professor Brendan Mackay

Across Australia, conservation planning has mainly involved setting aside for conservation a portion of the available land parcels (e.g. in a national park, nature reserve or conservation park), with the surrounding land largely not managed for conservation. This conventional approach typically focuses on achieving, as efficiently as possible, a target level of protection for representative samples of each mappable class of ecosystem (in practice, usually defined in terms of major vegetation types), populations of particular target species (typically threatened plants and animals), and/or other specified special features. Conservation targets are usually expressed as a nominated percentage level; for example, many planning exercises seek to protect within conservation reserves 10–30% of the historic extent of every vegetation type. The regional conservation objective is that, taken together, this set of conservation lands will comprise a comprehensive reserve network.

Assumptions underlying this approach are that:

- target levels are scientifically robust, and protection at that target level will provide long-term security for the represented biodiversity
- the environmental layer (often vegetation types) used in target setting provides a good surrogate for the distribution of most elements of biodiversity
- such a system of protected areas can ensure the long-term conservation of biodiversity at all levels (see Box 1.3), and will be reasonably insulated from the impacts of the surrounding land uses
- natural values can be traded off against competing land uses by identifying alternative locations (e.g. habitat loss at one location can be compensated by protecting habitat at another location)
- there are enough land parcels available to protect the full suite of environments.

Unfortunately, these assumptions are often invalid. Land-use allocation exercises are often mired in details, such as the demonstrable value of a particular site considered in isolation. In such debates, the currency of conservation values is discounted compared to the land's more clearly explicit or perceived market-based economic value. The end result is usually a landscape dissected by contrasting isolated land uses, with conservation areas scattered throughout a landscape largely transformed by modern land-use activities. Generally, these conservation areas are too isolated and too few in size and number. They are also usually in areas of low economic value (often because the land is infertile, too steep, or otherwise of low productivity) or great risk (such as low-lying land in Western Australia's salinising Wheatbelt).

In other words, the approach was designed to wring some conservation outcome within regions that typically had been largely fragmented and disturbed, where creating conservation reserves of some of the remaining patches of native vegetation was the best of the limited options available. This failure to take into account the ecological processes and connections that make the landscape work and keep it healthy has caused major environmental problems throughout Australia (e.g. the Murray-Darling basin and Western Australian Wheatbelt). Failure to protect hydro-ecological processes, for example, has caused salinity and degraded rivers; as a result, there are major salinity issues on farmland, and the numbers of many nomadic and migratory species have greatly declined due to the removal and degradation of key habitats. In most cases, the degradation of ecological processes is due to the accumulated impact of incremental changes that alter the country (e.g. another paddock sown to exotic pasture grasses, a few more megalitres diverted for irrigation, another patch of tree clearing), repeated tens or hundreds of times over a region.

Therefore, the conventional approach that focuses on achieving arbitrary target levels of protection for conservation elements such as species and habitat types will not protect the future of the Great Western Woodlands for two reasons:

1. It fails to incorporate the landscape-wide ecological processes that sustain natural values. For example, however large the protected area network may be, some critical processes will at times depend on lands and resources outside national parks. Without that access, species and other natural values will ultimately decline and degrade as the ecological connections and interactions that they depend upon break down.
2. The approach does not recognise or maintain the greatest conservation asset of the Great Western Woodlands: the extensive connectedness and intactness of its landscape.

It is critical that we learn the lessons of past mistakes, and adopt a new strategy for ensuring the survival of the Great Western Woodlands.

Living in the land

The sustainability approach described above incorporates and moves beyond core protected areas and into managing whole landscapes in ways that support and enhance local communities and Indigenous landholders. For a range of social and economic reasons, there is a need for development in some areas of the Great Western Woodlands. However, if the natural values of the Great Western Woodlands are to be retained, then that development must fit the nature of the country. In effect, we propose to invert the conventional approach and consider the entire Great Western Woodlands as a single conservation entity where nodes of human activity are carefully managed for their conservation impacts, analogous to the way the Great Barrier Reef is now managed. If the long-term goal is to manage biodiversity across the entire landscape, then all of the elements that make up the Great Western Woodlands must be considered.

To ensure the long-term protection of the region's natural values, priority should be given to developing and improving the economy in ways that are compatible with that. Economic opportunities based on environmental conservation need to be fully explored and developed. The concept of developing a 'conservation economy' makes sound ecological and economic sense for the region. Activities that would benefit the environment and provide viable income-generating opportunities include management of parks, control of invasive plants and animals, and managing fire to maximise carbon storage and biodiversity in the region. Moreover, well-managed and extensive areas of natural vegetation may increasingly be expected to provide economic and other social benefits through the carbon economy.

These kinds of compatible natural resource management activities would provide benefits for all Australians, ensuring a natural base for tourism and for commercial, recreational and other forms of resource use. Indeed, such activities are already a significant part of some regional economies in the Woodlands. In some communities, the 'conservation economy' may also provide direct social benefits by alleviating underemployment, maintaining cultural traditions, and improving health. Such social benefits would serve to improve outcomes from, and reduce economic costs associated with the current delivery of health and welfare services.

Conclusion

The responsibility to prepare a detailed plan for appropriate development and conservation management across the Great Western Woodlands rests with us all. Even knowing the little we do about the ecological significance of the region, it is clearly an outstanding part of Australia's heritage, and we would be remiss if we failed to seize this unique opportunity. We encourage people across the region, and all interested Australians, to participate in determining its future.

This report has been written for all those individuals, communities and organisations with an interest in the region. The authors hope that the report will act as a catalyst in bringing together people to discuss the central challenges that must be met if the region's biodiversity is to be conserved in perpetuity. Stakeholders include Traditional Owners, local communities, shire councils, the Western Australian and Federal Governments, mining and tourism companies, four-wheel drive clubs, apiarists, wildlife enthusiasts, conservation organisations and the science community. It is time to look more closely at the region's future and to develop a comprehensive plan to protect it.

Our focus here has been to provide information on the natural values and ecological processes of the Great Western Woodlands so that they can be understood and appreciated, and to provide input into a process that delivers a sustainable future. Without recognition and protection through an appropriate conservation management plan, the amazing biodiversity found in the Great Western Woodlands will continue to be at increasing risk.

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Opposite image. Mark Godfrey

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David Mackenzie is an experienced advocate for the conservation of Western Australia's unique plants, animals and wilderness landscapes. Having lead The Wilderness Society WA's conservation efforts over 15 years, he played coordinating roles in campaigns to protect Australia's South West forests, outback woodlands, Ningaloo Reef and more recently near-shore and deep sea marine environments. He has tertiary qualifications in both engineering and science.

Dr Alexander Watson is the Outback Conservation Manager for The Wilderness Society. He currently works as the Great Western Woodlands campaign manager to ensure the region is appropriately managed on the basis of good science and through listening to people who live and work in the region. An ecologist by training, Alexander conducted his PhD research in forest ecology, and has worked on conservation related campaigns including Albatross protection in New South Wales and old growth forest protection in western Canada.

Dr James Watson is a post-doctoral researcher at the University of Queensland. In this role James is conducting applied research using modern systematic conservation planning techniques to identify optimum restoration activities for biodiversity in fragmented landscapes and critical habitats to protect in large wilderness areas. Prior to this James was the National WildCountry Coordinator for The Wilderness Society for two years where he coordinated the national WildCountry program. James obtained undergraduate training at University College (University of New South Wales) and was awarded a Doctorate of Philosophy at the University of Oxford. He is currently the policy officer and president-elect of the Society of Conservation Biology.

About the Text Box Authors

Keith Bradby is Director of the Gondwana Link collaboration. In that role he supports a range of groups in the development of strong conservation and restoration programs across 1000kms of south-western Australia. Over the past three decades Keith has worked across this region in many roles, including beekeeper, native seed collector, local enterprise consultant, government policy officer and community activist. Before taking on his role with the Gondwana Link groups, he was instrumental in the tightening of controls on land clearing in south-western Australia.

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Bill Bunbury is a broadcaster and author. He has won four international and national awards for his radio features including the New York Gold Medal for Best History Documentary in 1996 for his feature TIMBER FOR GOLD, the story of the WA Eastern Goldfields woodlines, and later a book on this topic with the same title,. He has written nine other books on Australian history.

Josie Carwardine is a research scholar in the Centre for Applied Environmental Decision Analysis at the University of Queensland. She is interested in decision making processes for conservation planning and management. Her current research focuses on integrating multiple objectives into a framework for making economically and environmentally sustainable management decisions in terrestrial and freshwater systems.

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David Knowles is an experienced field naturalist, biosurveyor, author, wildlife photographer, and ex zookeeper. In addition he and his wife Fleur have successfully run a small business called Spineless Wonders. They are dedicated advocates of macro-invertebrates in the public arena and have positively role-modelled macro-invertebrates to tens of thousands of children and adults over the past decade.

Professor Brendan Mackey is a professor of environmental science at the Australian National University. He is director of the ANU WildCountry Research and policy Hub. Brendan has a PhD in tropical plant ecology and his research and teaching is in the areas of macroecology and environmental biogeography, with applications to conservation biology.

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Professor Hugh Possingham completed Applied Mathematics Honours at The University of Adelaide and after attaining a Rhodes Scholarship, completed his D.Phil at Oxford University in 1987. In July 2000 Hugh took up a joint Professorship between the Departments of Zoology & Entomology, and Mathematics at The University of Queensland. Professor Possingham is currently an ARC Federation fellow (2007 – 2011) and Director of a Commonwealth Environment Research Facility – Applied Environmental Decision Analysis.

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Sean Stankowski is currently a PhD candidate at the University of Western Australia with specific interests in evolution, ecology and conservation. He is currently investigating the use of molecular genetic markers to explain the processes which lead to evolutionary diversification on islands.

Emeritus Professor Michael Soulé was a founder of the Society for Conservation Biology and The Wildlands Project and has been the President of both. He has written and edited 9 books and published 160 articles on biology, conservation biology, and the social and policy context of conservation. He is a Fellow of both the American Association for the Advancement of Science and the American Academy of Arts and Sciences, has received a Guggenheim Fellowship, is the sixth recipient of the Archie Carr Medal, was named by Audubon Magazine in 1998 as one of the 100 Champions of Conservation of the 20th Century and is a recipient of the National Wildlife Federation's National Conservation Achievement Award for Science.

Dr Barry Traill is Director of the Wild Australia Program, a joint wilderness protection program of Pew Environment Group and The Nature Conservancy. He is a terrestrial wildlife ecologist with particular expertise on temperate and tropical woodlands. Barry has worked as a conservation advocate for 25 years on a wide range of nature conservation issues.

Dr Kerrie Wilson is the Director of Conservation for The Nature Conservancy Australia Program. In her role Kerrie leads the development of conservation programs across Australia and manages an Ecological Science Program which is focused on addressing priority applied conservation research gaps. Prior to joining the Conservancy, Kerrie was a senior researcher at The University of Queensland during which time she developed innovative frameworks for the allocation of conservation resources and techniques to monitor and evaluate conservation outcomes.

Matt Watts research interests are in systematic conservation planning, decision support systems, geographical information systems, systems analysis and design, and computer programming. He wrote the C-Plan decision support system, and is now modifying Marxan software to incorporate multiple zoning and costs.