Nature UNMASKED

SEE AND INTERPRET VICTORIA'S ECOSYSTEMS

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Front cover image: © Nick Vertsonis Photography. Azure Kingfisher (*Ceyx azureus*): the predator and its prey – transparent to avoid detection – but not this time.
Rear cover: Snow Gums. © Stephen Platt.

Disclaimer

Foreword

THIS BOOK is written for people who have a keen interest in nature and want to know more about it. It assumes very limited prior knowledge of the natural world. It's a book about how living things are connected with their environments and each other in the State of Victoria, Australia.

In this book, I look broadly at some of the ecosystems that are easily recognisable and that have been studied. The book is not intended to be an exhaustive catalogue of all ecosystems. Rather, the aim is to introduce some ecosystems and come to know something about how we currently think they function. The focus is not on threats and dysfunction.

Importantly, when you're in nature, the book challenges you to look, to ask questions about what's going on and to seek answers. I offer examples of what to look for to help interpret nature. Even very experienced ecologists are constantly surprised by what they find and will struggle to predict specific outcomes, so don't worry if it seems like 'the more you know, the more confusing it seems to get'. It *is* complex. Google Scholar (type it into your internet browser) is an excellent entry point to the published scientific literature. Be surprised by what we *don't* know.

How to read this book

CHAPTER COVERS invite you to look at an image and guess what is going on. An interpretation is given at the end of the chapter. A brief 'teaser' of interesting points starts each chapter. Details relating to these points are included in the chapter text. Chapters are perhaps best read when you are visiting the ecosystem. References are indicated by numbers in the text and given in full at the end of the book. They are useful starting points if you wish to delve further into a topic. Useful general references are also listed at the end. Where I suggest an explanation about a topic, it will be indicated by 'perhaps', 'may be', 'speculate' or similar words. Scientific names are provided as these are the most accurate if you wish to obtain further information on an organism. Recognised common names are capitalised (i.e., 'Black-tailed Wallaby' is *Wallabia bicolor* whereas a 'black-tailed wallaby' is a dark-tailed wallaby of unknown identity). Scattered throughout the book are brief overviews of types of organisms titled 'Getting to know our [e.g., birds]'. Note that due to availability some images were not taken in Victoria and so may show minor variations from Victorian species. I have sought to use language that is accessible and, where appropriate, have included the corresponding scientific term in brackets. Inevitably in a book of this kind generalisations are made and ideas framed based on current knowledge. Be aware that there are very often exceptions to the rule and that much is yet to be learnt.

Acknowledgements

SUCH A book cannot be produced without the prior effort of hundreds of people, though their exploration, research, archiving, photography…to them all, I say thank you.

To those who helped direct me to useful reference material or contributed ideas – Mark Norman, Mark Rodrigue, Lucas Bluff, Juliet Lowther, Andrew Bennett, I say thank you.

To all the photographers and copyright holders who kindly let me use their images either through Creative Commons licensing or direct contact, thank you. I acknowledge the skill, time and cost of obtaining images which you have let me use freely. Your generosity has made this book possible.

I am indebted to those who read and commented on the text – Dr Lucas Bluff, Dr Matthew Colloff, Kate Stothers, Dr John Koehn, Prof. Nicholas Williams, Philip Ingamels, Juliet Lowther, Mark Rodriguez, Josh Griffiths, Dr Katie Howard, Dr Nick Clemann, Prof. Michael Clarke, Dr. Rohan Bilney, Alex Maisey, Dr Phil Papas, Prof. Andrew Bennett, Assoc. Prof. John Morgan, Robyn Ball, Jane Duckworth, Ilonka Bokor, Ros Smith – your collective knowledge and insights have improved this endeavour.

Dedication

TO MY parents, Lorna and Ken, for their support and allowing me to pursue my passions in life. To my many mentors and in particular Leigh Ahern and David Ashton. To my wife Kathleen, and children Carolyn and Meredith, whom I will always love. To all those people who have a love of nature and who have contributed to its protection – your selfless efforts have given future generations the greatest treasure – life in all its wonderous diversity and beauty.

Contents

The exquisite beauty of nature as shown by this Small Duck-Orchid (*Caleana minor*) covered in morning dew at Providence Ponds, Gippsland.
© Stephen Platt.

I knew almost nothing

IT BEGAN during my youth with collecting tadpoles, crabs, Emperor Gum caterpillars and birds. The unifying theme was death.

The tadpoles I collected from fire dams on picnic excursions to the forest lived happily in an ice cream container apparently eating their boiled lettuce, putting on growth and developing legs until suddenly and mysteriously they died.

I recall the cold sand underfoot on early morning ventures along the coastline of Phillip Island to pillage crabs from under rocks on reef platforms. They also lived happily in their seawater containers until death inexplicably arrived.

Emperor Gum Moth (*Opodiphthera eucalypti)* caterpillars were found on local gum trees, their magnificent cylindrical blue-green body with red, orange and blue hairy protuberances making them a prized find. I watched as they ate and ate gum leaves, growing fatter and fatter until one day they began weaving a silken cocoon of golden thread which eventually enclosed them. In hiding, they managed to do the unbelievable, to rearrange their bodies and emerge as what appeared to be a completely different organism with large, brown, scaly wings supporting intense blue and black false eyes and feathered antennae. They no longer ate and, after laying some eggs, died.

My bird aviary provided an opportunity to see the life of birds up close – Zebra Finches (*Taeniopygia guttata*) wove bottle-shaped nests into which tiny, white, oval eggs were laid. The hatchlings raised their scrawny, down-covered necks begging for food from their parents that busily collected it on their behalf. Some of the chicks died before leaving the nest. Others were hunted down and killed by mice. Wild Grey Butcherbirds (*Cracticus torquatus*) attacked the caged birds ferociously from outside their aviary. Even the birds themselves attacked each other, sometimes leading to death. Two exotic male Cuban Finches (*Tiaris canorus*), a father and son, had to be separated before they killed one another. A pair of newly arrived Long-tailed Finches (*Poephila acuticauda*) died sheltering overnight in a Zebra Finch nest.

What was wrong? Death appeared to stalk my animal collections. In the midst of so much death, the question became: what sustains life?

The problem was my failure to understand the deep connections these animals had with their environment. That my frogs and crabs needed to breathe air – tadpoles as they metamorphose into frogs, shore crabs as the tides recede; that Emperor Gum Moths only live for a short time before being replaced by the next generation, that birds compete with each other, that they are preyed upon and that Long-tailed Finches from tropical environments can find winter in Melbourne too cold for survival. In short, I had no notion of ecology, or of habitat, or of the life cycle of animals.

Nevertheless, I was inspired by nature – the excitement of being in the bush with its extraordinary, often weird, sometimes dangerous, and always adventuresome opportunities.

Tadpoles
© Friedrich B. CC SA 2.5 Generic.

Purple-mottled Shore Crab (*Cyclograpsis granulosis*). © Stephen Platt.

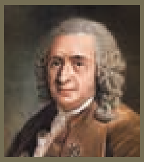
Emperor Gum Moth caterpillar
© Elizabeth Tasker

Male Zebra Finches
© Jim Bendon. CC SA 2.0 Generic

The beginnings of ecology

THOUGH UNDOUBTEDLY integral to the culture of indigenous Australians, it is only recently that western science has started to understand and document how organisms interact with their natural environment. Putting names to species (taxonomy), is a foundation of modern ecology – 'the relations of organisms to one another and to their physical surroundings'. A timeline of key participants and their contribution, with an emphasis on important figures in Victoria, is given below. See 'Recommended reading' for biographies.

Carl Linnaeus **1707–1778** develops modern taxonomic nomenclature (i.e., genus & species). Naming species was a pre-requisite to discussion and understanding of how they relate to one another and the environment.

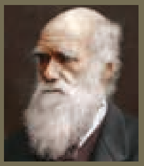


Alexander von Humboldt **1769–1859**, a wealthy Prussian who spent five years travelling in South America, realised that all organisms are related to their environment and published his thoughts in a series of books. His insights inspired others.

In **1853**, Baron **Sir Ferdinand von Mueller** **1825–1896** is appointed as the first government botanist for Victoria and establishes the National Herbarium of Victoria, followed by the Royal Botanic Gardens and National Herbarium in 1857. His dedication and hard work laid the foundation of our knowledge of the plants in Victoria.

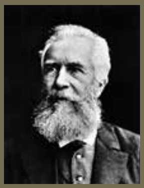
In **1854**, **Sir Frederick McCoy** is appointed as the first Director of the National Museum of Natural History and Geology, as it was then known, now Museums Victoria.

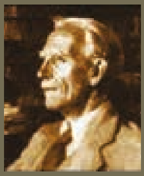
Charles Darwin's seminal book 'The Origin of Species' is published in **1859**. It revolutionises our understanding of the mechanisms by which organisms are intimately related to their environment through natural selection and evolution with a basis in genetics.



The **Field Naturalists Club of Victoria** is established in **1880**.

Ernst Haekel **1834–1919** a German biologist and disciple of Humboldt, invents the term 'ecology'.





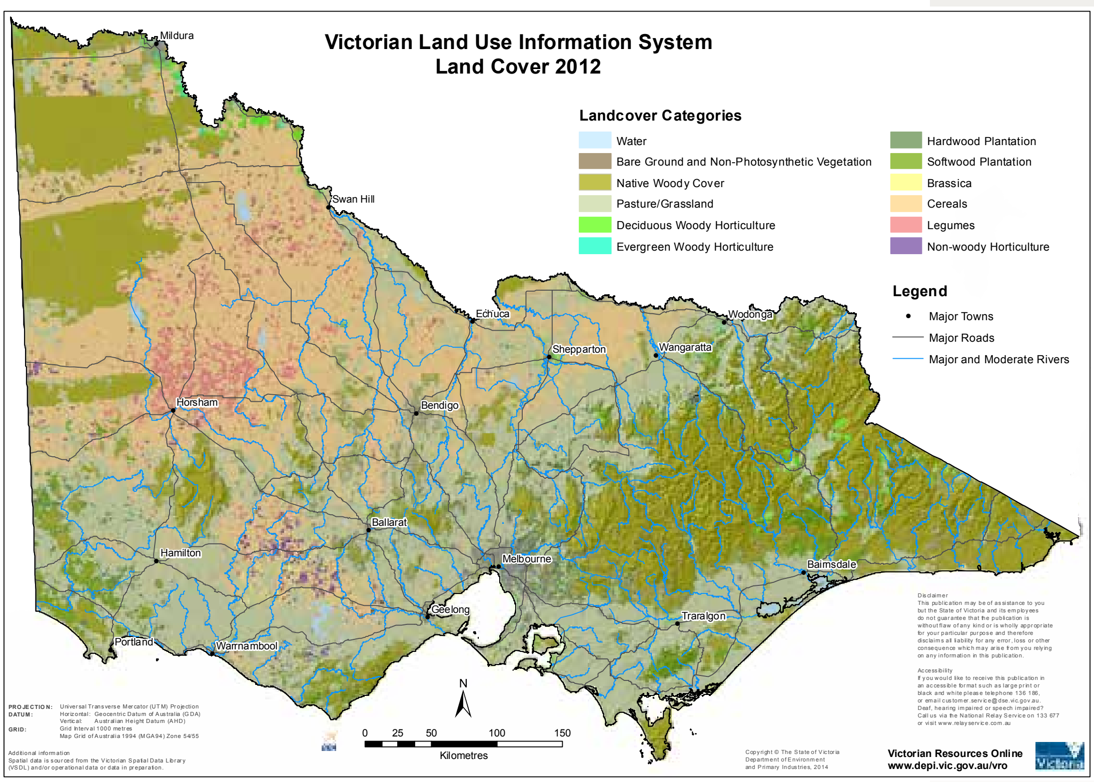
In **1935**, **Sir Arthur G Tansley**, an English botanist, defines the term 'ecosystem', first used by Roy Clapham in 1930. Tansley is a founding member of the first professional society for ecologists, the British Ecological Society 1913, and first editor of the *Journal of Ecology*.

1950s – the **first university academics** are appointed to ecological positions in Australia. The **Ecological Society of Australia** is established in 1959, one hundred years after the publication of 'The Origin of Species'.

The first statewide *Flora of Victoria* is published in **1973** thanks to the hard work and diligence of **Dr Jim Willis** and contributions by many botanists and field collectors based at the National Herbarium of Victoria and elsewhere.

Exploration of Victoria's vegetation

This extraordinarily detailed state-wide map of Victoria's vegetation was produced in 1869. A larger version of this map is on the inside back cover. Victoria: distribution of forest trees / compiled by Arthur Everett from the record maps in the Office of the Surveyor General, and other authentic sources, under the direction of R. Brough Smyth ; engraved by William Slight.– Rev. ed. Source: State Library of Victoria, Trove: https://trove.nla.gov.au/work/7375460?q=victoria+distribution+of+forest+trees&c=map



Victoria's current 'land use'. Source: Victorian Resources Online.

The idea of ecosystems

WHEN ALEXANDER von Humboldt, a wealthy Prussian naturalist, travelled through South America between 1799 and 1804 he made a remarkable observation – that similar life forms occurred at different elevations on a mountainous volcano, and he guessed that these related to the physical environment.[1] Not only that, but he was aware that similar associations occurred on European mountains. At high altitude, plants were squat, compact and small-leaved whilst at low elevations they were tall, luxuriant and broad-leaved. Physical factors, including temperature, rainfall, snow duration and soil development, vary with altitude and he thought that these were determining what plants and animals could live there. Study of these associations was later named 'ecology' by one of Humboldt's disciples, Ernst Haekel.

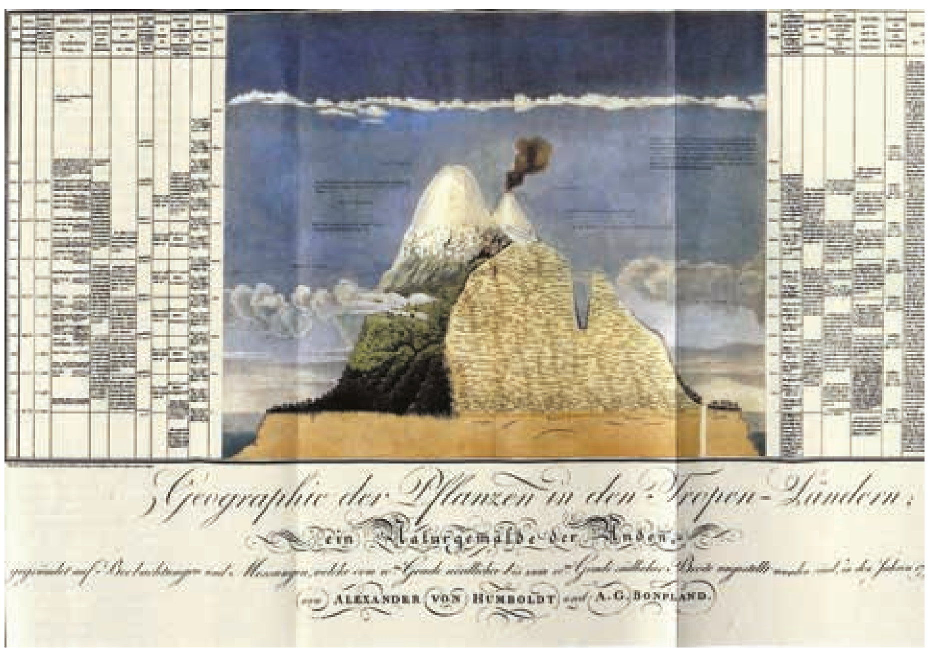
"Look deep into nature, and then you will understand everything better."

(Albert Einstein)

An 'ecosystem' is, as the name suggests, a *system* in which various plants, animals and their environment interact. Today, various classifications of ecosystems have been adopted but, in reality, there are no hard boundaries.

The first attempt to map the 'ecosystems' of Victoria was undertaken in 1869, with the production of a map showing forest trees. The government Botanist, Baron Ferdinand von Mueller, provided notes on the flora associations. Thus, less than 70 years since the coastline was first mapped[2] and just 34 years after the settlement of Melbourne, we had a fairly comprehensive picture of the distribution of forest types and the plants in them.

Their original nature was not to last much longer. From the beginnings of pastoralism in the 1830s and during the gold rush in the 1850s, ecosystems were altered rapidly across vast areas.



Humboldt's Chimborazo Map shows Ecuador's highest mountain volcano in cross section with information on the plants occupying different zones.

Source: Wikimedia Commons. Public domain.

Victoria – a land of contrasts

THOUGH RELATIVELY small in area, Victoria is remarkably diverse. Hills and mountains (to 1805m, Mt Buller), sufficient to attract seasonal snowfalls, stretch from the centre to the north east with some outliers in the west, notably the Grampians and Otways. The area south of the Great Dividing Range receives higher rainfall as cold fronts pass along the coast. Travelling north-west, rainfall declines sharply to semi-desert conditions. Dry storms accompanied by lightning create fires in the hot summer (max. recorded 50.7°C). The northern border is delineated by the Murray River, Australia's largest (2,508km).

Climate factors typically set limits to the broad-scale distribution of plants.[3]

Victoria's geology and soils are generally old or sandy and nutrient poor, though there are exceptions including the vast volcanic plains in the south west.

Such a diverse landscape harbours a great variety of ecosystems of plants and animals. To date, we have identified*:

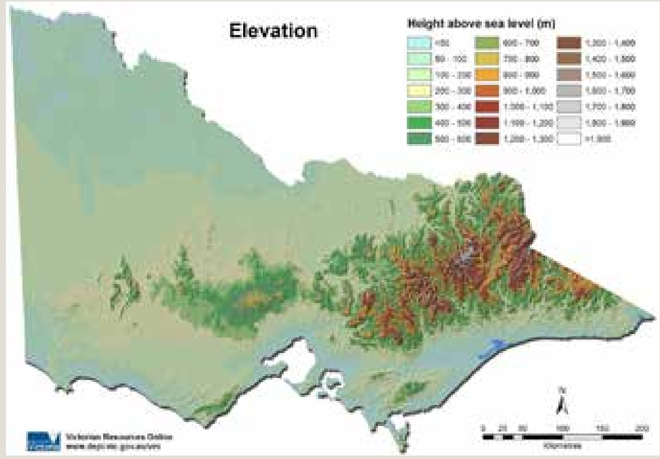
Plants (native vascular)	Taxa	Threatened	%
Monocotyledons	1160	420	36
Dicotyledons	2589	1085	42
Ferns & fern allies	100	50	50
Conifers	8	0	0
Plants (introduced/non-native)	1484		
Total (native plants)	**3857**	**1555**	**40**

Animals (vertebrate)	Taxa	Threatened	%
Mammals	144	49	34
Birds	534	104	19
Reptiles (incl. 5 marine)	141	40	28
Amphibians	50	15	30
Fish (freshwater)	172	37	22
Animals (introduced/non-marine)	81		
Total (native animals)	**1041**	**245**	**23**

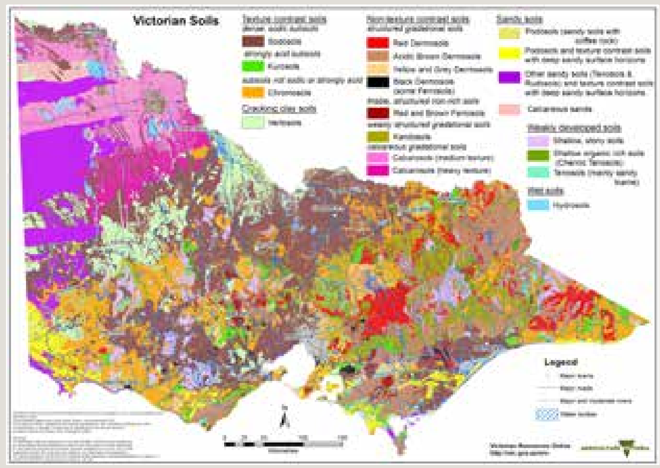
- 13,963 taxa (currently described) of native, non-marine invertebrates and 245 native marine invertebrates of which 104 and 10 taxa are threatened respectively.
- 1,043 taxa of marine fish.

*these numbers are still in flux due to various factors including ongoing surveys, modern genetic analyses, recognition of variants and delays in publishing taxonomic studies.

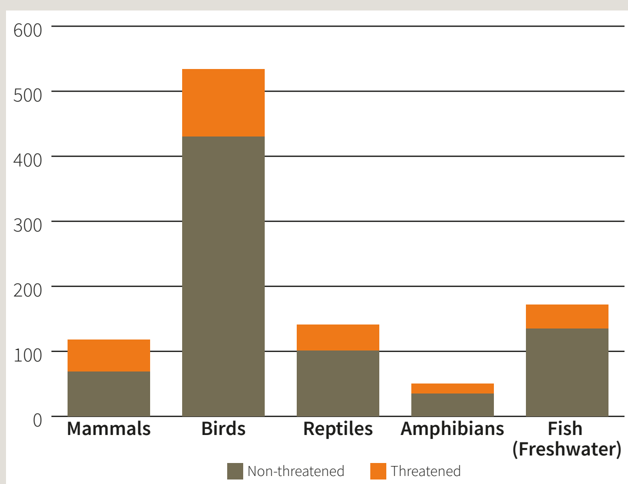
The last mammal species to be discovered in Victoria was the Long-footed Potoroo (*Potorous longipes*) when, in 1967, a male was caught in a dog trap south west of Bonang in East Gippsland and another killed by a car. It wasn't formally described until 1980.[4]



The State of Victoria is small in comparison to other jurisdictions of Australia. None-the-less it has a diverse landscape and extensive coastline. Source: Victorian Resources Online.



Soils of Victoria. Native vegetation associated with more fertile soils has been disproportionately cleared for agriculture.
Source: Victorian Resources Online.



Proportion of vertebrate animals that are threatened.

The effect of isolation

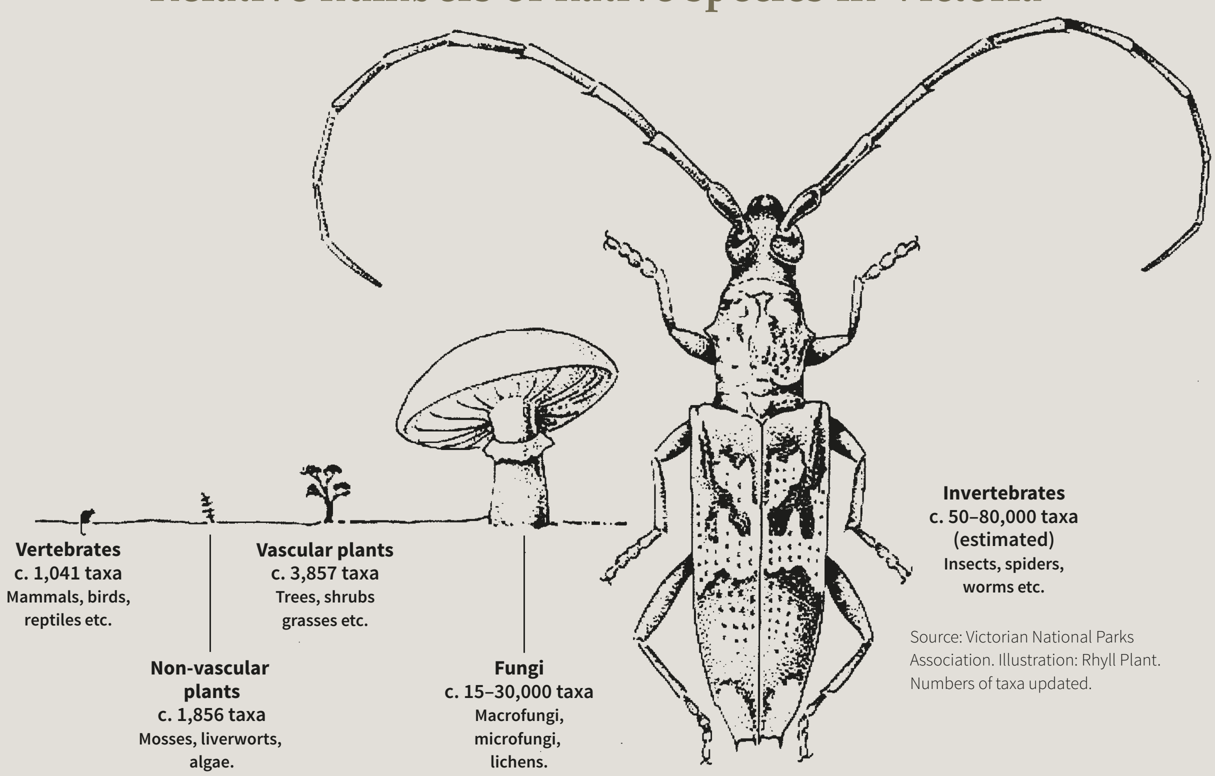
THIS UNIQUE biological legacy is the result of a geological history that saw Australia break off, around 132 million years ago, from a very large land mass located at the south pole called Gondwana and drift as an island northward. That continents drift was first proposed by Alfred Wegener in 1912. At first a fantastical idea, the mechanisms are now well understood. The Australian continent is still moving north at around 7cm per year. Over time, large temperature fluctuations, including glaciations, occurred and in warm periods seas covered various parts of the Victorian landscape. Recently, a maritime climate and increasing dryness has led to eucalyptus forests and woodlands, aided by fire, replacing the once extensive rainforests of Gondwana. In the south west of Victoria, extensive volcanic activity created huge lava plains.

The marsupial (pouched) mammals, which had evolved prior to the breakup of Gondwana, found themselves largely protected from competition with placental mammals, that evolved after them, by Australia's surrounding oceans.

When compared with other countries, Australia has very high levels of endemism (i.e., species found only in Australia): 69% of mammals (including marine mammals), 46% of our birds, 93% of reptiles, 94% of amphibians and 93% of flowering plants are endemic. Other groups, such as the eucalypts, are mostly found in Australia or nearby.[5] This is due to our relative isolation from other land masses for a long period of time.

Australia separated from Gondwana, the ancient southern land mass, around 132 million years ago. Map: Google Earth.

Relative numbers of native species in Victoria



Source: Victorian National Parks Association. Illustration: Rhyll Plant. Numbers of taxa updated.

Understanding the shape of a gum tree

As trees age, they take on the scars of battle – twisted, bent and broken by the wind and snow, burnt by fire, attacked by invertebrates, parasites and disease. It's intriguing to think that we can learn about the past by looking at the anatomy of a tree. What can you see in this image? Can you explain the shape of this Snow Gum? © Ken Griffiths.

Understanding the shape of a gum tree

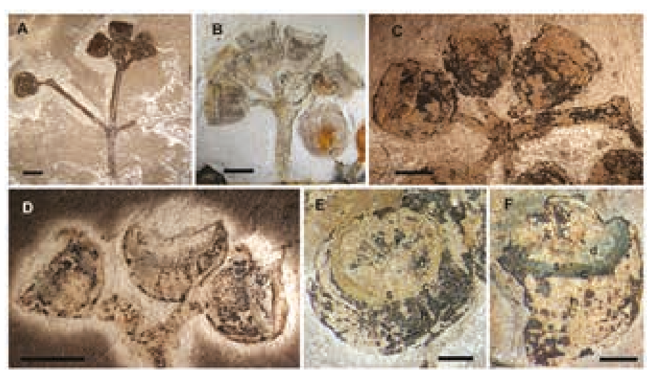
The remains of this Snow Gum, living on The Razorback near Mt Hotham in Victoria's alpine region, tell a story. On the left of the image is the thick original trunk killed by a hot fire in 2003. To its right, the white stems are the shoots that grew from living buds at the base of the trunk (lignotuber) but were killed by a second fire in 2006. This fire charcoaled the dead original trunk but not the young stems covered in bark. They died, their bark fell off and their wood 'silvered'. A second cohort of live, leaf-bearing stems is now growing from the surviving, underground lignotuber. These stems have grown about one metre high and 1–2cm in diameter in 12 years, which suggests that the original trunk was very old despite its small size. If you know what to look for, you can discover many stories written in nature. © Stephen Platt.

WE ALL know what a tree looks like, don't we? There are short ones, tall ones, skinny ones, fat ones, bent ones, wide ones, buttressed ones. But why do trees, and gum trees in particular, look like they do?

Trees form forests and woodlands and tree-dominated ecosystems once covered most of Victoria and, for that matter, the Earth. Victoria is dominated by a single tree genus named *Eucalyptus* – gum trees (family Myrtaceae).[6] The tree has had a huge influence on wildlife habitats and the species that occupy them. Without trees, many forms of wildlife could not exist. Trees even influence the anatomy of wildlife. For example:

- the size of hollows they produce which places limits on the size of animals that can fit into them
- their diameter and the foraging opportunities created by their bark and foliage
- their height, scalability and density of foliage and the refuge it offers from predators.

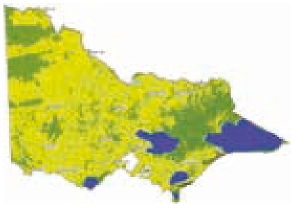
Mountain Ash 'gumnuts' (fruits) and seeds amongst chaff. Inside each seed is the information needed to grow the tallest flowering plant on Earth. © Stephen Platt.



Fifty-two-million-year-old fossils of *Eucalyptus* fruits found in Patagonia, South America. The genus is around 109 million years old. © Maria Gandolfo *et al.*[7]

Gum trees begin life as seeds that are tiny; about the size of a pinhead. This is true no matter how big the tree eventually grows. Inside the seed are the complex genetic instructions – the 'recipe' of traits that have been selected for survival in an environment. As environments differ, so do the genetic instructions for growth. The seed is an incredibly small package in which to store such a lot of information! But inherited genes are only part of the story.

The shape of gums in wet forests



In areas of high rainfall and rich, fertile soils (i.e., unlimited water and food), the main driver of tree form is surviving against competitors, often of the same species. Thus, in the mountains of central Victoria, Mountain Ash (*Eucalyptus regnans*) seedlings display extraordinary growth rates of two to three metres or more per annum as they race against each other in a life and death competition for sunlight.

Sunlight provides the energy for tree growth. Leaves are nature's solar panels that collect it. In gums, they are usually sickle-shaped and, after being horizontal in the juvenile period, hang pendulously capturing light at either end of the day whilst avoiding the blistering heat and water loss of the midday sun. A fine tip helps drain water from the leaf surface that could otherwise encourage fungi.

Those seedlings that fall behind in the race for light will eventually lose access to sunlight and are destined to die. You can see them in the forest as thin or dead spars amid the larger live trees. Slowly, as the spars fall, the forest becomes less dense with fewer, larger trees.

The survivors will reach the limits of tree height. This is determined by the capacity of the sun to draw water up the thin tubes inside the tree (xylem vessels), something that must continue without interruption for the life of the tree. The mechanism is a simple one. Energy from the sun evaporates water molecules from pores (stomata) on the leaf surface. Water molecules stick to one another so that when one molecule evaporates it pulls the others up behind it and so on along the entire height of the tree. This chain of water has a limit and it's about the height of the tallest flowering trees on the planet, the Mountain Ash, which grow to 90 metres high and weigh around 100 tonnes (dry weight) when mature (equiv. to 16 African elephants).

Gum leaves are nature's solar panels, producing energy for growth. Globally, photosynthesis captures 130 terawatts of energy, or around 3,170 Snowy Hydro schemes, per annum. © Stephen Platt.

Mountain Ash – the world's tallest flowering plant, grows straight and tall as it competes for sunlight, usually against its own species. © Stephen Platt.

These are also the heaviest forests on the planet with over 1,000 tonnes per hectare of living, above-ground biomass or over 1,800 tonnes per hectare if you include dead material on the forest floor.[8]

They form dense, vertical stands, supporting a relatively small canopy of leaves. The canopy is domed as each small, growing branch strives to find maximum exposure to the sunlight. During the rapid growth phase there are no significant side branches as they would soon be overgrown, lose access to sunlight, and be useless. Once a tree emerges above its competitors, side branches may develop. Grouped together, these trees support each other during strong winds.

Their mature root systems are shallow, exploiting the nutrients concentrated as vegetation rots in the topsoil. There is no need for roots to grow down to water in these wet environments.

They are usually single species' stands because few other species can compete against Mountain Ash's extraordinary capacity for rapid growth and massive height.

Fire is a rare occurrence in this wet ecosystem, occurring every 75–150 years. Mature Ash hold their seeds in small, fire-resistant capsules high up in the tree canopy. On the infrequent occasions when conditions are dry enough a fire inferno can occur killing the thin-barked adult trees and triggering a mass germination of seedlings in the post-fire ash bed – up to 4.5 million per hectare.[9] The fire-killed adults (stags), remain as grey ghosts amid the regrowing forest and will eventually fall to earth over the next 100 years or so. In one study, half had fallen over a 24-year period[10] (or 2–4% per annum). The ability that other gums have, to reshoot from buds under the bark or at the base of the tree after fire, has been lost in Mountain Ash, so seed survival is essential for their replacement.

Browsing by animals is not a significant issue due to the speed and volume of regrowth.

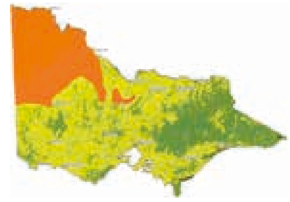
Large, old Mountain Ash may have small buttresses at the base. These help to prop up and stabilise such tall structures as they do for Notre Dame Cathedral in Paris. The extremely straight and tall trunk, and small canopy form of Mountain Ash, is appropriate to the conditions it experiences. Competition for growth in the presence of unlimited resources explains the shape of Mountain Ash, but what of other species?

Bushfire-killed Mountain Ash near Marysville. Note the high density, straight form and few side branches. Intense competition for light, in this case within the same species, is a major factor determining the shape of these trees. © Stephen Platt.

A race for survival in which there are winners and losers in the competition for light and nutrients. © Stephen Platt.

Small buttresses help Mountain Ash to support its great height. © Stephen Platt.

The shape of gums in the Mallee



In the Mallee, an area of north-west Victoria, gum trees have a vastly different architecture.

This is a hot, dry, sandy, infertile environment. Mature trees are relatively short and typically have many stems coming from a broad, woody base. Seedlings germinate and grow in typical fashion for a dry environment focussing on putting their roots down and outward quickly in the search for water rather than into above-ground growth in height. Access to water is the main determinant of survival in the Mallee. Outstretched surface roots take up water and prevent near neighbours from growing. Tree density is low and tree height restricted by limited water availability.

Typical multi-stemmed mallee eucalypt. © Stephen Platt.

◀ **What is the reason behind this mallee tree's odd shape? The very large mass at the base of the tree is a lignotuber containing buds from which shoots can sprout following a fire. Normally just buried, the fact that it is exposed suggests that the soil surface has eroded. We can see two large trunks. These are what remain of many shoots that emanated from the lignotuber after a previous fire. Over time, the other shoots circling the lignotuber have been broken off by wind or died of other causes. Based on the size of the lignotuber, it is likely that this process has occurred many times after many fires. Fires here are infrequent occurring every 40–90 years. Growth is slow due to lack of water. Thus, the root system, which is not killed by a fire, could be hundreds to thousands of years old and the upper parts at least 100 years. Given that the existing tree will have control of local soil and water resources through its surviving root system, successful addition of new seedlings into the immediate landscape (recruitment) might occur once in a thousand years or more and only after the tree dies, perhaps in a severe drought.** © Stephen Platt.

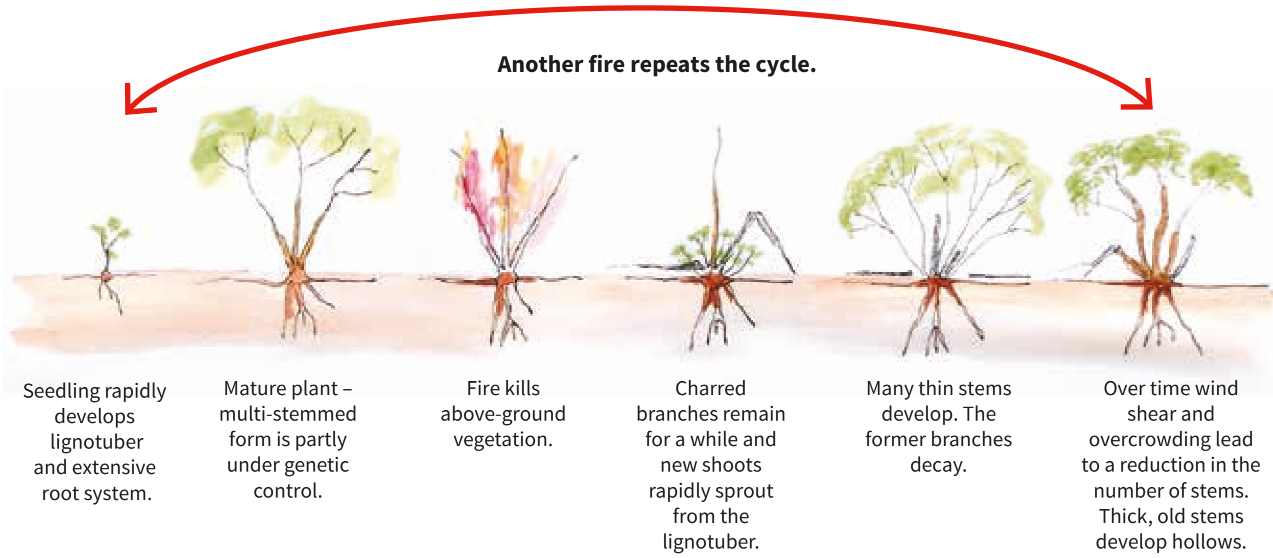
Fire is a regular feature of the hot, dry, lightning-affected Mallee environment. In anticipation of fire, mallee eucalypt seedlings (there are numerous species of mallee) develop a lignotuber in the first months of life. Most people know this as a 'mallee root'. As trees cannot flee an oncoming fire, their above ground branches are inevitably burnt and usually killed. However, the roots below ground continue to remain alive and to supply water and nutrients. The root system can thus be many generations older than the visible stems might indicate, in some cases they may be thousands of years old. Remember that when you next observe someone throwing a mallee lignotuber ('mallee root') onto the fire – it may be older than any antique furniture in existence. After fire, stems re-sprout from the lignotuber forming a dense cluster (see pages 13, 70). Over time, outstretched side stems may be ripped off by wind shear and others may be overshadowed, die and collapse. Hence the tree will gradually re-form to have one to a few main vertical stems with a wide canopy of leaves until the next fire resets the cycle. The short stature, multi-stemmed form, and woody base of a mallee gum is suited to and a consequence of its extremely arid, fire-prone environment.

Trees of mallee form also occur above the snowline. In this case, very cold winters that limit growth rate, rain falling as snow rather than available water, and fire combine to create a similar problem for tree survival.

This ironbark looks mallee-like, having multiple stems, but if you look closely, you will see the sawn stump where it was cut down by humans and not fire. © Stephen Platt.

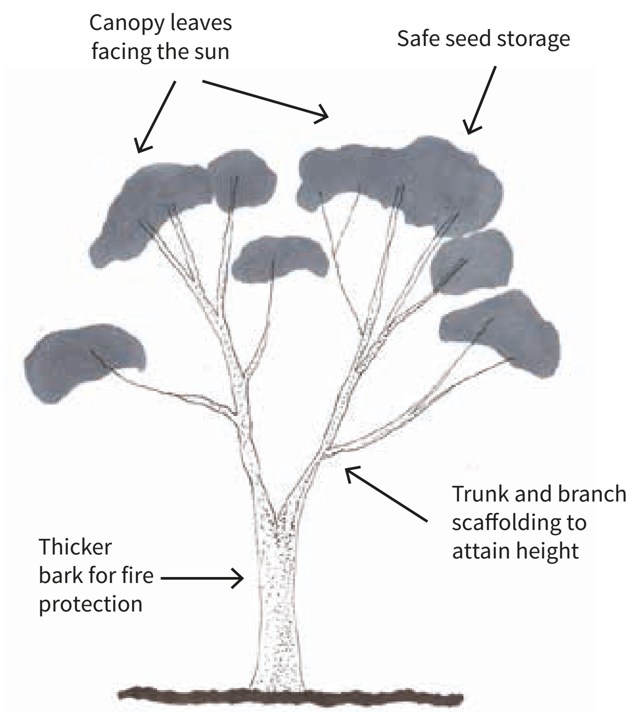
This ancient Snow Gum (*Eucalyptus pauciflora*) has a massive lignotuber. The multiple stems are survivors from when buds in the lignotuber re-sprouted after a previous fire. The root system is much older than the above ground parts. Despite slow growing conditions above the snowline, this individual has grown to be huge because it is in a location protected from intense fire. Note the snow-flattened grasses and the similarity in shape with mallee gums. © Stephen Platt.

Mallee fire cycle



The shape of gums in moderate climates

Between the extremes of Mountain Ash and Mallee gums are a wide range of forest and woodland trees. They have a similar Y shape, repeated as branches divide to access sunlight. Their height and spacing largely reflects water availability.



A typical forest gum tree shape. Height confers advantages on trees. They can harvest light before it reaches shrubs and ground covers. During a fire, their branches hold seeds out of the reach of intense flames and leaves away from terrestrial browsing animals. However, height and bulk come at a cost in terms of water requirements, nutrients and stability. When the balance tips, shrubs and ground covers dominate.

The spread of branches to form a domed canopy is more pronounced the greater the distance between trees because light can penetrate the sides and branches grow toward the light. Thus, tree canopies that are semi-circular probably grew in an open woodland whilst those with a narrow canopy developed in a forest.

The direction of growth of trunk and branches reflects the direction of incoming light during their formation. Those branches that grew close to a neighbour may have had to grow away from the shadow it cast. Thus, the twisted shapes of branches as they wind their way through a maze of shadow and light.

When a whole tree collapses, due to flood, wind or rain-softened soil, the resulting tree shape can be comb-like with new vertical stems arising from the original, now horizontal, trunk.

This tree has fallen over but remained attached to its living root system. The fall appears to have followed a fire that damaged the base of the original tree. New vertical-growing 'trunks' have formed along the original, now-horizontal, trunk either from former branches or buds. They have grown skywards and replaced the tree's leafy canopy. The tree would have lived on but for a second fire that killed it (indicated by the silvered wood and lack of living bark). © Stephen Platt.

Termites have excavated most of the dead heartwood of this branch whilst leaving the living wood untouched. The process of hollow formation is critical to so many of our hollow-using wildlife. © Stephen Platt.

River Red Gum showing self-pruning of branches (yellow arrows). The lowest opening (orange arrow) is due to a broken branch. © Stephen Platt.

Tree trunks have important functions. The trunk lifts foliage above that of competitors providing unlimited access to sunlight. It places the vulnerable small branches and their seed capsules away from damage by low intensity bushfire and grazing animals on the forest floor.

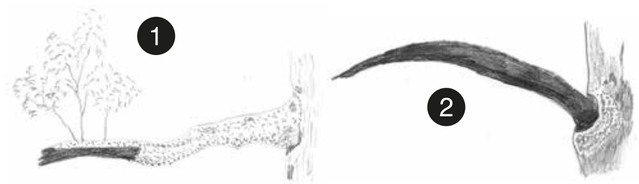
The trunk must be solid enough to carry the weight of the canopy or withstand a flood but flexible enough not to break in high winds or heavy snowfall.

The formation of a branch-free trunk is no accident. Gum trees have a wonderful way of dealing with wasteful appendages – they drop them off. As the canopy grows higher, the leafy branches that developed lower down are deprived of sunlight by those that form higher up. These lower branches are deliberately discarded in a process called 'self-pruning'. The light-deprived branch is shut down, dies, rots and will eventually fall or be broken off, perhaps pushed by a strong wind or heavy animal. You can see these dead branches on the lower parts of living trees. They supply much of the fallen firewood collected by campers and are a major source of openings to hollows used by wildlife.

Most of a standing tree is dead. Living material or 'sapwood' forms a thin, outer skin, just under the bark. It covers an inner core of dead wood or 'heartwood' which is vulnerable to fungi, termites and invertebrates such as wood-eating, beetle larvae ('witchetty grubs'). They can survive and grow deep inside the tree without the need for light. Fungi may gain entry when the tree's protective bark is cracked during a drought, or is perforated by wood-eating invertebrates or scarred by fire. As the heartwood decays, it collapses leaving a hollow centre to the trunk and larger branches. This process usually takes upwards of 70–100 years for small hollows to form, much longer for large hollows. Natural hollow formation is an important characteristic of eucalypts, particularly the smooth, gum-barked species (Subgenus Symphyomyrtus).[11]

Hollow entrances used by wildlife form in one of two major ways. Either a self-pruned branch falls off leaving a smooth, circular entrance hole or wind breaks a branch exposing the hollow interior and leaving a characteristic splintered entrance. Lightning may also occasionally break branches and expose their inner hollows, generally at the apex of a tree.

Bracket fungus fruiting body and crack showing where the fungus may have gained entry to the inner heartwood. © Stephen Platt.



The two main types of formation of hollow openings are shown here. 1. Wind-pruned – at left a low, extended branch has snapped in the wind as shown by its splintered end. New, vertical shoots have appeared from living wood just behind the snap. 2. Self-pruned – above the broken branch is a self-pruned branch in the process of decay. It will rot back to the trunk then fall off leaving an entrance hollow the size of the branch. These dead branches are favourite daytime roosts for Tawny Frogmouths. © Stephen Platt.

A lightning-affected stringybark in East Gippsland. The electric current flows through the living, water-filled sapwood of the tree which heats and expands explosively. © Stephen Platt.

These hollow types are easily recognised. Unlike a self-pruned branch, which terminates near the trunk and is surrounded by a smooth opening, wind-derived breaks are usually along a living branch and have a splintered opening. A rule-of-thumb used by campers to break branches for firewood without vibration is to hit them on a sharp edge one third of the distance along their length. Perhaps the same physics applies to the break point when wind fractures a branch leaving roughly one third attached to the tree? Lightning may, on occasion, also split topmost branches and expose hollows.

The diameter and height of a gum tree is a good indicator of whether it is likely to have hollows. Gum trees with a large trunk diameter (>80cm) have more, deeper hollows.[12] Wet forests contain more hollows than dry forests.[13] Trees with dead wood in the canopy also usually contain more hollows. Hollows tend to be more numerous with greater height. Few are found within five metres of the ground.

Behind the name – 'gum' tree

AT THE time of European settlement of Australia interest in plant products, including anything that oozed from a tree, was high. Plant exudates were shipped back to England for use in such things as medicines, paints, varnishes, rubber and chewing gum. 'Gum' trees were thus labelled as a source of these commercially valuable gum substances.[14]

An old River Red Gum showing spouts (yellow arrow), a fire scar (red) as well as galls (green) and broken branches. © Stephen Platt.

A particular type of hollow can be found in some gum trees, such as old River Red Gums (*Eucalyptus camaldulensis*), called a 'spout' (named after a tea pot spout). Spouts bend out and down and end in a hollow entrance. They are the remnants of large branches that developed on a tree in an open environment where sunlight could reach the base of the tree, such as on a riverbank. Thus, the branches bearing leaves grew out toward the sunlight and down, bent by their own weight (River Red Gum timber is very dense and heavy ~900kg/m^3). Wind shear can break off these outstretched, lateral branches exposing the hollow inside. Hence, a spout is formed. Its downward projection prevents rain entry making it a prized shelter for wildlife as rain can kill young animals in hollows. For example, in a long-term study of Galahs, after a particularly heavy rainstorm, coupled with low temperatures, many hollows were flooded killing the incompletely-feathered chicks.[15]

Australian Owlet Nightjar (*Aegotheles cristatus*) enjoying the sun whilst sitting in a spout, as they often do. © Geoff Park.

Which came first, the wildlife or the hollow?

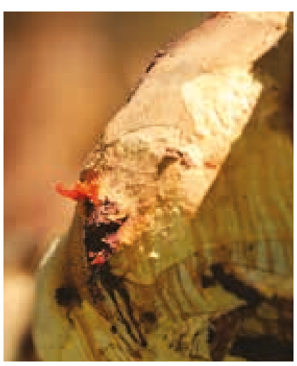
SELF-PRUNING, WIND shear and lightning, which create hollow openings, and excavation of heartwood to form hollow interiors of trees, has had a profound effect on our wildlife. Many animal species are reliant on hollows for shelter and/or breeding. In Victoria, sixty-one species of vertebrate are hollow-dependent – meaning they must use a hollow for all or part of their life cycle – and a further 36 species use hollows opportunistically.[16,17] This dependence indicates that hollows have been a reliable habitat feature in our forests and woodlands for millennia. It contrasts with the pine and conifer forests of the northern hemisphere (boreal forests) where birds, like woodpeckers, must often make their own nesting hollows (the main reason woodpeckers peck holes in *live* trees is to find food including sap or invertebrates. *Dead trees* are excavated for breeding).

Native species also create and modify hollow openings. For example, this Sacred Kingfisher (*Todiramphus sanctus*) is excavating the entrance to a breeding hollow in a dead tree by the Yarra River. © Stephen Platt.

Sugar Glider – hollows are selected on many characteristics including 'just fit' entrances that will exclude any larger predators. When larger animals are trying to eat you, you need somewhere safe to hide! © Steve Parish.

Hollows are an important factor in shaping the range of wildlife species we see in our treed landscapes. A variety of branch sizes leads to a variety of hollow entrance sizes. Wildlife species select hollows with an entrance size just large enough for them to enter. This means that larger predators are unable to access the hollow and eat them. Hence, hollows of different entrance sizes tend to be occupied by different species and not all hollows are useful to a particular species. There are little animals that fit into little hollow entrances (e.g., Feathertail Glider), medium-sized animals for medium hollows (e.g., Sugar Glider[18,19], Brush-tailed Phascogale) and larger species for larger hollows (e.g., Common Brush-tailed Possum, Powerful Owl). Hollow size and animal size are thus inter-linked. Our wildlife's extensive use of hollows is indicative of the high-level risks, from predators and climate, outside.

Large 'cancerous' growths on the trunk and branches of gums are an indication of infection or disease. Galls can be caused by a range of invertebrates including wasps, flies, beetles, psyllids, coccids, moths, nematodes and mites as well as bacteria and fungi.[20] They are more common on older individuals and are probably a symptom of declining health with age (i.e., older individuals are less able to defend themselves against infection). Yes, trees actively defend themselves against all sorts of enemies. Resin, often seen dripping from a wound in the tree trunk is used in defence against invertebrates and as a wound sealant. When hardened and fossilised into amber, insects may be trapped inside and preserved.



This very large gall on a River Red Gum may indicate age-related, declining ability of the host to resist infection. © Stephen Platt.

Notice the unusual bare patches on the trunk of this Yellow Gum (*Eucalyptus leucoxylon*) at Werribee Gorge. They have been created by Galahs. Various explanations have been put forward to explain why they are made including to deter snakes (the bare wood being less easy to climb) that the patch serves as a 'brand' or 'signpost' saying that these hollows are taken or perhaps this activity prevents wood covering over the hollow entrance. © Stephen Platt.

Evidence of past fire can be seen imprinted onto living trees. Usually this is a triangular, inverted-V scar at the base of the tree, often on the uphill side where phytofall (leaves, twigs, branches etc.) accumulates and fuels the fire. Often the tree's outer, living skin will have tried to grow back over the fire scar and a rounded edge will have formed. In some cases, this has occurred multiple times following repeated, low intensity fires and is evidence of regular, non-lethal fire.

Why are our trees evergreen?

SEASONAL LOSS of leaf cover is a characteristic of European trees but not those in Victoria, even when they are subject to seasonal snow. Production of leaves costs energy and requires nutrients. Our nutrient poor soils, low in some essential trace elements, probably make the cost of being deciduous too high to allow leaf replacement annually.

Browsing and over-browsing by native herbivores can also affect tree shape and health. Browsing of seedlings influences their shape toward a multi-stemmed form. Over-browsing may occur when native predators decline or are absent. For example, in the absence of predators Eastern Ring-tailed Possums can eat the leaves of a tree to the point where it will appear almost leafless. Look for trees with their only remaining leaves at the outermost, bottom branches. Usually this co-occurs with a very dense understorey, needed by the possums for safe movement between food sources.

Dieback, which appears as death of the finer branches at the top of a tree, may have many causes including drought, insect damage and salinity.

The architecture of a gum tree is thus a result of its genetics, its fight for light and other resources, the scars of battles with wind, fire, flood, drought, salt, pest animals and disease. The shape and condition of a tree can give us clues about the history of a forest or woodland – about when the current generation of trees started life (their age), whether this was at the same time (even-aged), whether individuals were in the open (spreading form, bending toward light), if and when they were burnt (fire scars, bark char), and indications of their health (galls, mistletoe, lerps). All these challenges must be faced whilst the tree must also achieve balance in form, so as not to fall over, and reproduce. When you next wander through a forest, see if you can interpret its history from the evidence shown in the shape (form, anatomy, morphology) of its trees.

If you look carefully at every creature, you will discover a 'design' that neatly fits with its evolutionary history and environment.

Phytofall = 'leaf litter'

Rather than perpetuate the existing, unfortunate term for fallen leaf and branch debris 'leaf litter', I have created the alternative term 'phytofall' (= plant fall) for use in this book. The term is defined here as the fallen material, not the process of it falling.

Trees that have survived a couple of fires may be propped up by a few 'legs', just enough to remain alive and standing, at least in the short term. The initial fire exposed the dead heartwood of the tree. This dead wood is readily ignited by subsequent fires. Post Black Saturday 2009. Robertson Gully, Marysville. © Stephen Platt.

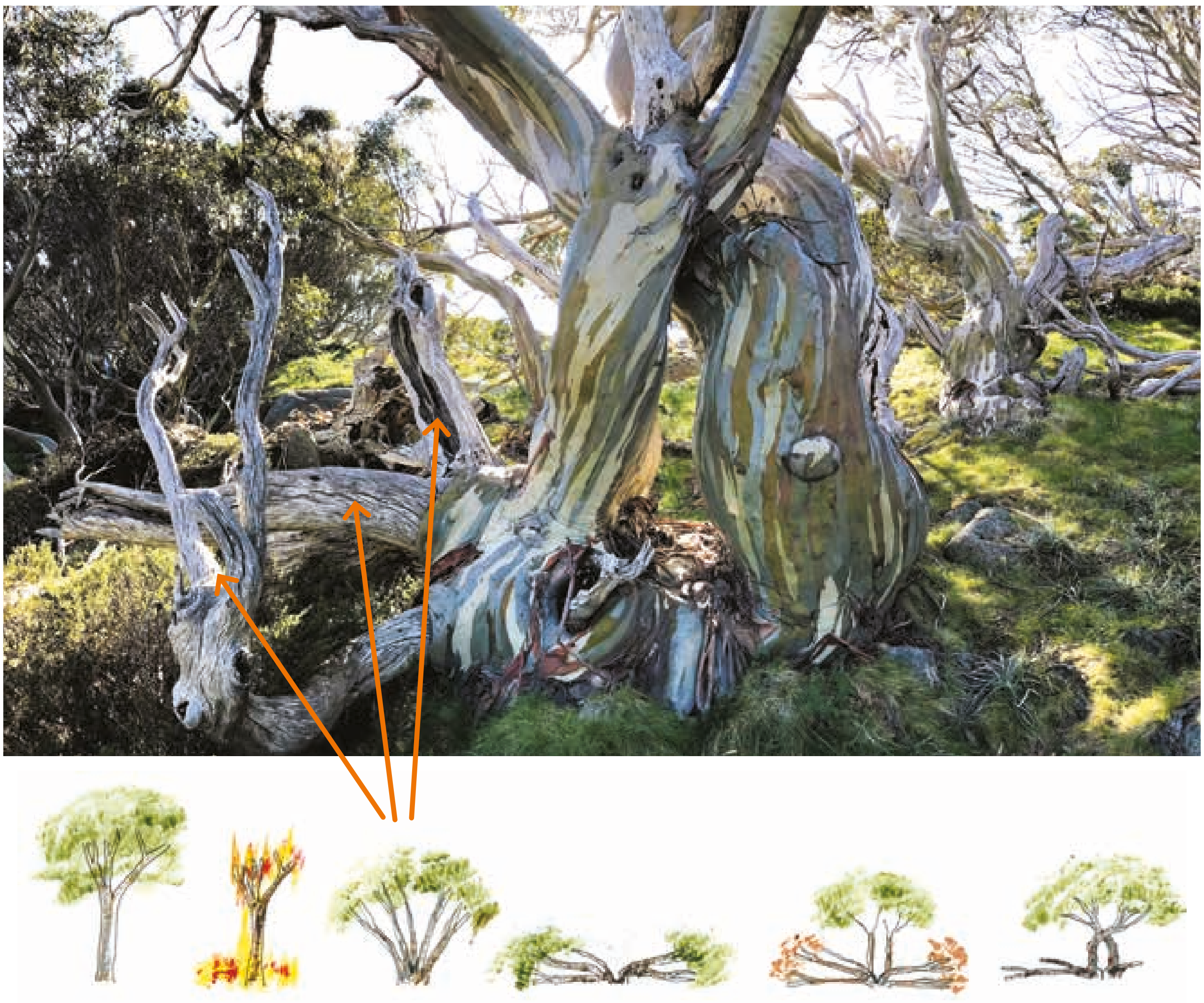
Wind, the weight and pruning effect of snow, can influence a tree to grow away from the prevailing weather such as shown by these fire-killed Snow Gums *(Eucalyptus pauciflora)* on Mt Cobbler with trunk and branches that are almost horizontal. Flexible branches allow this species to bend with the weight of snow. © Stephen Platt.

CHAPTER COVER: What can we see in this image? There are two trunks apparently joined at the centre. To the left and behind are large, dead 'branches' on the ground.

An interpretation of what has happened here is: There was a mature Snow Gum on this site. At some time, it was burnt and coppiced creating multiple stems. Perhaps 100 years went by and the new stems became quite stout before a very heavy snowfall split the tree down the middle – perhaps due to an old fire injury. The tree remained alive as its roots were unaffected. The split explains why there are limbs to the left lying on the ground – they are the former coppiced stems. The split tree then grew new shoots on either side of the split, which are the trunks we see today.

They spiral around each other as a consequence of the search for light. As they established a canopy, it overshadowed the former coppiced stems lying on the ground and these either self-pruned (i.e., died back to the main trunk) or died from snow cover.

The girth of the two current trunks is large, especially in this alpine environment, and suggests a great age for this tree, especially given its many life stages. Its rocky, ridge-top position may have helped protect it from severe fires. It appears relatively healthy and the shedding bark indicates new growth suggesting it has many more years to live. Following recent extensive fires, there are few specimens remaining like this one (at a national park location in NSW).



Original mature tree.

Coppice after fire creates multiple stems.

Heavy snow splits tree down the middle. Tree remains alive.

New shoots replace trunk & canopy. Shadow of new canopy leads to self-pruning of coppiced stems.

Tree today. Two entwined stems formed as they compete for light.

The Blandowski Expedition to the junction of the Murray and Darling Rivers

IT'S A tale of strong and eccentric personalities, tragic endings and the thirst for knowledge. The Blandowski Expedition was an early attempt by European settlers to document the fauna of north-west Victoria and, over time, has gained in significance as many of the species they encountered are now extinct.

The expeditioners left Melbourne in the gold rush year of 1856 with their field equipment – five horses, two drays, four tents and a full set of tools with implements, and also a photographic apparatus – headed for the junction of the Murray and Darling Rivers in north west Victoria. William Blandowski, was the first staff member (zoologist) of the newly established Melbourne Museum of Natural History. His assistant, Gerard Krefft, complained of Blandowski's poor organization, inefficiency and "obnoxious set of rules for the guidance of his party".

Two years earlier, in October 1854, Alfred Howitt had gone on a collecting expedition with Blandowski to the Mornington Peninsula. Howitt, the brilliant bushman and naturalist who later on ably carried out the task of 'rescuing' the remains of the Burke and Wills expedition, described Blandowski as "a dreamy philosophising German [superimposed] on an Australian bushman, but I cannot find that it is an improvement on either."[21]

Of fifteen employees on the journey, Krefft was the only one to stick out the twelve-month expedition. With them were over 300kg of photographic equipment 'that never would work', 51kg of dried German vegetables that induced Krefft to vomit and 5lbs of the best starch and two flattening irons used for laundering the commander's shirts and handkerchiefs.

After eight months camped near the river junction collecting wildlife and trading for specimens from local aborigines, who were paid the 'exorbitant sum' of one shilling per skin, Blandowski returned to Melbourne via Adelaide with a treasure chest of 16,000 specimens many species of which have never been collected there since. They included Western Quoll, Red-tailed Phascogale, Greater Stick-nest Rat, Desert Mouse, Bolam's Mouse, Pig-footed Bandicoot and Eastern Hare-wallaby.[22]

When Krefft asked indigenous people on the Murray to collect bats for him they refused because they regarded them as 'a departed friend and relative'. After Krefft caught one himself he was told it was 'brother belonging to black-fellow who kill lubra if you kill him'.[23]

The expedition collected 19 new fish species which Blandowski proposed to name after members of the Council of the Royal Society of Victoria. However, the members drew violent exception to what they saw as an insult by inferring they had the qualities of their namesakes. For example, a specimen named after one prominent member was described as a "fish easily recognised by its low forehead, big belly and sharp spine." [24]

At the end of the expedition, Blandowski returned to his home in Melbourne, rather than to the Museum, then off to Germany with many of the specimens. By this time the report of the expedition had reached England where the famous naturalist John Gould demanded that "glaring falsehoods" in the report be corrected, such as the misrepresentation of Rabbit Bandicoots (Bilby) "digging up the bodies of dead natives and devouring them."

William Blandowski, the first staff member of what would become Melbourne's Museum.
Source: National Gallery of Victoria.

Blandowski ended his days in a lunatic asylum.[25] Krefft remained in Melbourne where he became a famous zoologist, writing numerous scientific papers and books including on the snakes and mammals of Australia. In 1861, Krefft became a curator at the Australian Museum in Sydney where he remained until 1874. Whilst at the Museum, Krefft uncovered a scandal involving missing gold, which led to accusations the museum trustees were using its resources for their own benefit. In return, they accused Krefft of drunkenness, falsifying attendance records and selling pornographic (ethnographic) pictures.[26,27] This led to Krefft's dismissal and both he and his wife being illegally evicted from their living quarters at the Museum.

Gerard Krefft, 1850s.
Source: Australian Museum, Sydney.

A marvel of design, the Eastern Horseshoe Bat (*Rhinolophus megaphyllus*) has a body that allows it to survive in often harsh environments with many competitors and predators; to find food, breed and survive disease. Its strange-looking face allows this bat to detect obstacles and navigate in complete darkness using echo-location, its soft fur provides warmth for its light body, membranous wings of skin permit travel over large distances seeking food and hooked appendages allow it to hold on to cave walls where it roosts and breeds in colonies. It is a winning design as are the designs of all the incredible creatures that inhabit Victoria. For every animal we can ask – why has it evolved to be like this?

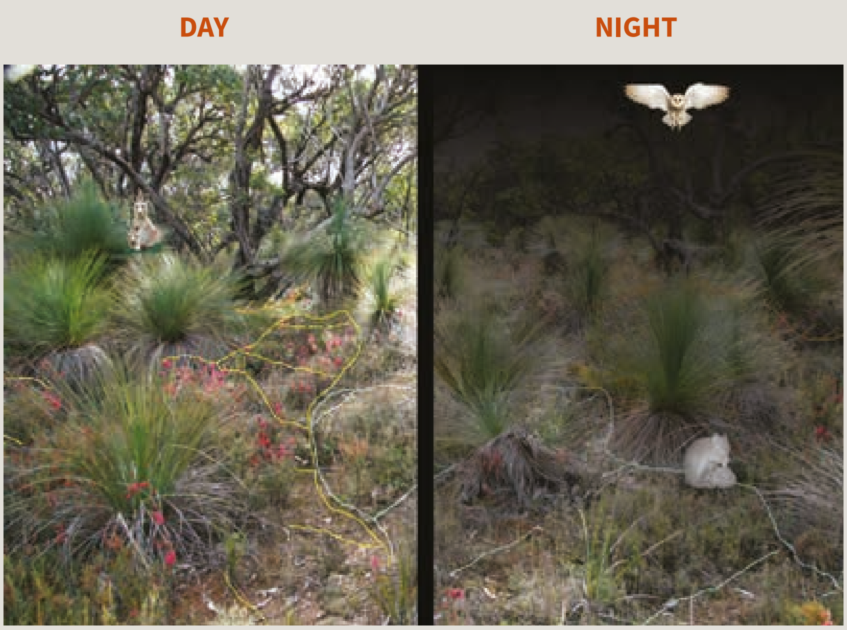
Reimagining what you see

WHEN WE look at native vegetation, we tend to focus on what is obviously before us. It is usually a daytime perspective. However, this is only part of the picture.

What we don't tend to see is:

- The variation in soil, rock and water holding capacity
- The mosaic of different fungi spreading through the soil
- The nitrogen-fixing bacteria associated with pea (leguminous) plants
- The site history including fire history and chemical (nutrient) history
- Which animal species appear and what happens after dark
- The activity of soil invertebrates
- The chemical signals including pheromone trails and scent marking left behind by animals
- The visual signals, such as on many flowers, written in parts of the light spectrum invisible to humans
- Microscopic animals in waterbodies
- Pathogens and diseases in soil, carcasses and living animals
- Connected root systems whereby what looks like several plants or a colony above ground turns out to be just one plant
- The prior influence of humans in removing species, introducing species, etc.

These factors are important in understanding the patterns of variation in ecological communities.



When looking at native vegetation we need to imagine what we cannot, as humans, see – the different soil fungi (represented by coloured lines), the animals that come out at night and so on. © Stephen Platt.

Getting to know our native plants

1. Hard Water-fern (*Blechnum wattsii*), **2.** Red-anthered Wallaby Grass (*Rytidosperma pallidum*), **3.** Cat's Claws (*Grevillea alpina*), **4.** Scrub Cypress-pine (*Callitris verrucosa*), **5.** Liverworts, **6.** Small Grass-tree (*Xanthorrhoea minor* subsp. *lutea*) flowering post-fire.

Getting to know our native plants

THERE IS a magnificent variety of native vascular plant species in Victoria[28] with around 3,857 taxa (see Table). Some 1,555 vascular plant taxa are considered to be threatened in Victoria[29] or around two-in-five. The main threats have been clearing of habitat and competition from introduced plants ('weeds') most of which have a garden or agricultural origin. Roughly two-in-five plant taxa in Victoria is introduced.

What is a plant? It isn't as easy a question as it might seem but I will ignore the complexities. Most plants have many cells, with *cell walls* made of cellulose (animals lack cell walls), are *immobile* once growing and use *photosynthesis* to obtain energy from light. Cell walls allow plants to attain great height. Immobility means plants will live their entire life-cycle in one place and environment. Photosynthesis enables plants to harvest energy from a fairly ubiquitous source – the sun.

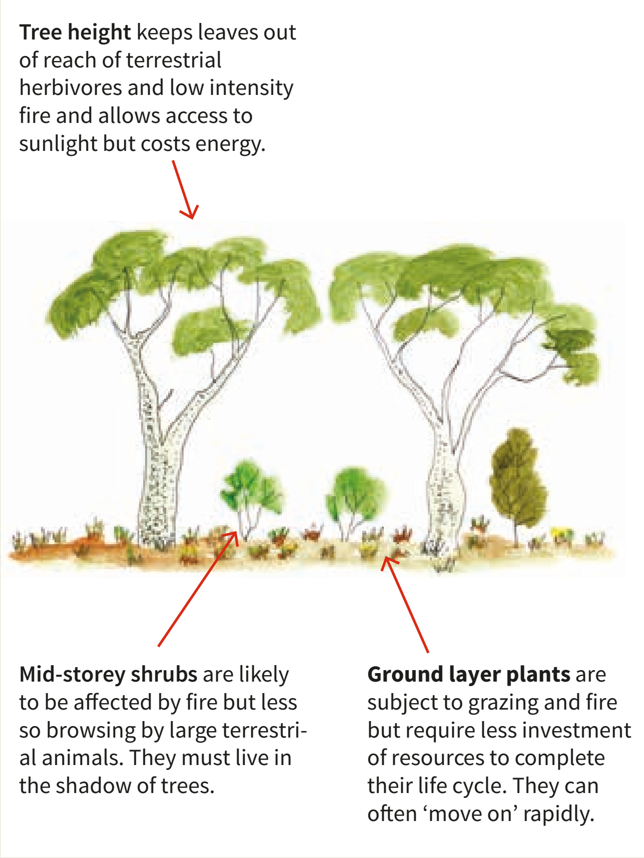
Vegetation attracts herbivores that fulfill their energy requirements by eating plants. Only around 10% of the energy captured from sunlight is converted by herbivores and only 10% of that reaches those animals that prey on herbivores. Hence, we don't find many animal predators compared to plant eaters.

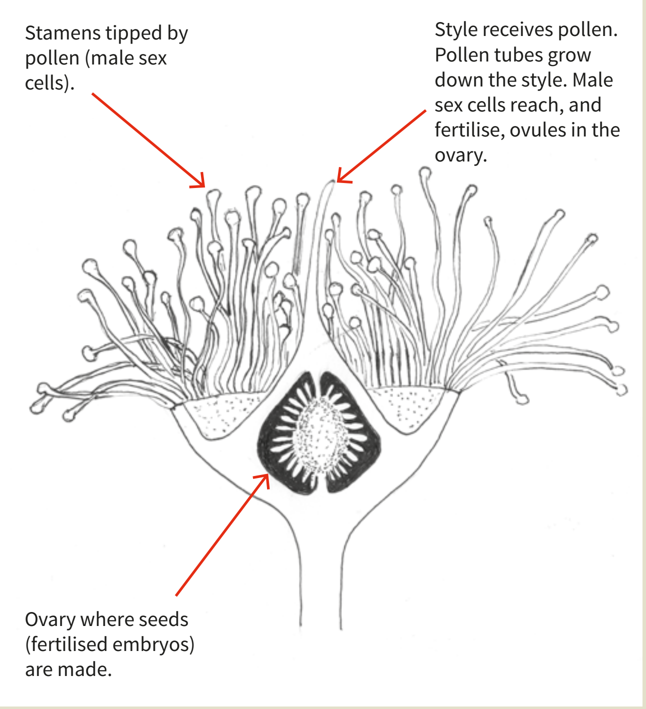
Because they are unable to move once established, plants tend to have high fidelity to particular environmental conditions. They must be capable of enduring change rather than running from it. Fire, flood, frost, snow, drought, salt, seed predation, insect infestation and disease must all be endured on-site whereas animals can often just move away.

Types of plants include trees, shrubs and ground covers. Trees are woody and usually have a single trunk. Shrubs are also woody but usually have multiple stems and are shorter than most trees. Ground covers may be grasses, ferns or herbs. Herbs are seed-producing plants that lack a woody stem. Multi-layered forests consist of tree, shrub and ground cover layers or 'storeys' (understorey = everything but the tree layer).

Layering of vegetation is no accident. Ecological influences have made it so. Lower, mid and upper storeys are present in many forests and woodlands. Plants have evolved to take advantage of the unique opportunities, and avoid the disadvantages, offered by particular heights (see diagram). These structural layers offer opportunities for animals to specialise and live together without direct competition (resource partitioning). For example, Striated Thornbills (*Acanthiza lineata*) feed by gleaning insects off eucalypt foliage high in the canopy whilst Yellow-rumped Thornbills (*A. chrysorrhoa*) forage mainly on the ground.

Plants (vascular)	Taxa	Threatened	%
Monocotyledons	1160	420	36
Dicotyledons	2589	1085	42
Ferns & fern allies	100	50	50
Conifers	8	0	0
Plants (introduced/non native)	1484		
Total (native vascular plants)	**3857**	**1555**	**40**
Plants (non-vascular)	**Taxa**	**Threatened**	**%**
Mosses & liverworts	542	60	11
Algae	1314		
Total (Bryophytes & algae)	**1856**	**60**	**3**





Structure of a River Red Gum flower cut in two.
Illustration: Stephen Platt.

Climbing Kangaroo Paw Fern (*Microsorium diversifolium*) with dark-brown, circular, spore-holding structures (sporangia) under some fronds. © Andrew Blackett.

Plant communication

Plants communicate through chemicals (enticing perfumes, toxic substances), colour (flowers), structure (thorns), electrical signals (that travel through the plant body and allow immediate and long term 'memory' responses to the environment)[30] and touch (e.g., hair triggers, root and fungi interactions).

Plant reproduction

There is a wide range of reproduction methods in plants. Many plants can reproduce both sexually and asexually. Asexual reproduction in plants may involve fragmentation, suckering/vegetative propagation, budding or spore formation. Sexual reproduction in flowering plants involves the male sex cell (as pollen, often bundled) being transferred, by wind, water or an animal, to the female sex cells (ovules). Most plants have flowers that are both male and female (with mechanisms to avoid self-fertilization) but sometimes the sexes are separate (e.g., She-oaks *Allocasuarina* spp.).

Reproduction in ferns involves spores from the parent plant growing to produce an intermediate, small plant (gametophyte) containing male and female sex cells. The male cells have to swim to fertilise the female cells and that's why ferns are usually restricted to wet environments.

Plants and their environment

Plants are affected by the environment in which they live. Physical characteristics such as rainfall, temperature, wind, daylength, soil, fire, salt, flood regime and so on determine what plants can live where. Considering just soil: the type, depth, acidity (pH), fertility, aeration, water content, permeability and soil fauna all interact to create a local environment that supports, or doesn't support, certain types of plants.

Plants have formed mutually beneficial biotic associations with other organisms including bacteria, fungi, ants and many others. For example, plants need nitrogen from air, which is 78% N, for growth and to function. Some plants are unable to access nitrogen without the help of nitrogen-fixing bacteria that live in nodules attached to their roots. In exchange the bacteria obtain sugars from the plant. Some fungi, which are not plants (they have cell walls made of chitin not cellulose. They absorb nutrients and are not photosynthetic), but are a major component of ecosystems, also form mutually-beneficial associations with plants (mycorrhizae).

Plant families

Plants are classified based on their physical and genetic characteristics into hierarchical groups of species, genera, families and so on. Some of the key plant families in Victoria are given below.

The myrtle family of plants (**Myrtaceae**) is a significant component of many ecosystems. It includes the eucalypts (*Eucalyptus* spp.), tea trees (*Leptospermum* spp.), paperbarks (*Melaleuca* spp.) and bottlebrushes (*Callistemon* spp.). Eucalypts dominate our landscape more than any other genus.

Wattles (**Mimosaceae**) and peas (**Fabaceae**) are also abundant elements of the flora, usually as shrubs.

At ground level there are many daisies (**Asteraceae**), and grasses (**Poaceae**). They often have a capacity to reproduce quickly, withstand grazing by herbivores and to cope with rapidly changing conditions.

The smell of wet forest

THAT DISTINCTIVE, earthy smell of wet forest has a name – 'petrichor'. It is the accumulated scents of compounds produced by bacteria, plants and lightning (ozone) stimulated by raindrops and detected with our nose.

Ecological role of plants

Through their ability to convert sunlight into energy, plants 'power up' all ecosystems (are primary producers). Without them, animal life as we know it couldn't exist. Plants are responsible for most of the oxygen content of the air we breathe, they produce the wood, leaves, roots, sap, pollen, nectar, fruits and seeds that animals eat, they provide the hollows, bark and foliage in which animals shelter, they are the highways for aerial movement, the soil stabilisers and the nutrient gatherers and dispersers. In some cases, they are the predators.

The huge variety of plants means that no trip into the bush is the same. Take the time to look at plants and what distinguishes one from another – they will never cease to amaze. We know so little about so many plant species.

Learning to identify plants

There are some fantastic resources available to help. See 'Recommended reading'.

Leaf shape

Why is a leaf the shape it is? It has a critical function – intercepting light and turning it into energy. Leaves come in a huge variety of shapes and sizes. There are numerous possible reasons for leaf shape including:

- Optimizing light interception and gas exchange
- Regulating temperature, particularly in extreme environments (hot, dry, frosty)
- Preventing herbivore browsing and infection
- Responding to limitations imposed by water availability
- Hydraulics and probably other factors working together resulting in a shape.[31]

The influences behind leaf shape are still being investigated.[32] Leaves are so varied and amazing in both their living and dead state and, of course, they are a major food source for humans.

The leaves of two species? No, this wattle has fern-like (bipinnate) juvenile leaves which grow into leaf-like phyllodes (which are actually modified stems) as it matures. © Stephen Platt.

Describing terrestrial vegetation

What is a forest and when does it become a woodland? How is vegetation classified? Various systems for describing vegetation have been developed. In 1970, a classification system was created based on vegetation structure.[33] A tree was defined as a woody plant more than 5m tall, usually with a single stem. A shrub is a woody plant less than 8m tall, frequently with many stems arising at or near the base. The structure of vegetation was defined in terms of the dominant plant form and the percentage of foliage cover of the tallest plant layer.

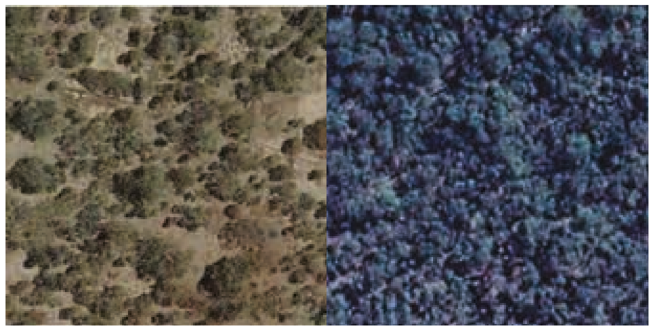
	Percentage foliage cover of tallest stratum			
Life form and height of tallest stratum	Dense (70–100%)	Mid-dense (30–70%)	Sparse (10–30%)	Very sparse (<10%)
Trees > 30m	Tall closed-forest	Tall open-forest	Tall woodland	Tall open-woodland
Trees 10–30m	Closed forest	Open forest	Woodland	Open-woodland
Trees 5–10m	Low closed-forest	Low open-forest	Low woodland	Low open-woodland
Shrubs 2–8m	Closed scrub	Open scrub	Tall shrubland	Tall open-shrubland
Shrubs 0–2m	Closed heath	Open heath	Low shrubland	Low open-shrubland

After Specht 1970

In the 1990s, 'Ecological Vegetation Classes' were made the standard unit for classifying vegetation in Victoria.[34] The plants (floristics), their lifeforms (tree, shrubs etc.) and ecological characteristics are used to broadly describe vegetation. For example, at Wilson's Promontory we have 'EVC 2 Coast Banksia Woodland' which is described as "Restricted to near coastal localities on secondary or tertiary dunes behind Coastal Dune Scrub. Usually dominated by a woodland overstorey of Coast Banksia *Banksia integrifolia* to 15m tall over a medium shrub layer. The understorey consists of a number of herbs and sedges, including scramblers."

Algae

Algae capture sunlight through photosynthesis but lack the stems, roots, leaves and specialised reproductive structures of plants. Except for their chloroplasts, they share some features with simple organisms (protozoa) and fungi. Whilst we are familiar with algae as seaweeds, algae also grow in freshwater including snow, on and inside animals such as turtles, in thermal springs, on tree bark and suspended in water as plankton.
(See also 'Getting to know our fungi, lichens and mosses').



Left: woodland, Woodlands Historic Park, Greenvale (20km NNW of Melbourne). Note the spacing between tree canopies. Right: forest, Lerderderg State Park (55km NWW of Melbourne). Tree crowns are touching and, if projected onto the ground, cover nearly the entire soil surface.
Source: Google Maps.

The magnificence of plants. Raymond Creek Falls, Snowy River National Park. © Stephen Platt.

River Red Gum – a forest of many floods

What can you tell about the history of this site from what you see in this image?

© Stephen Platt.

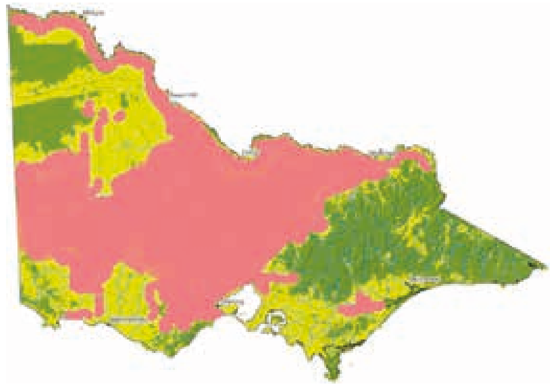
River Red Gum – a forest of many floods

***ANCIENT INDIVIDUALS** of 1000 years of age, a river giant that needs trees for breeding, a forest floor resident that dies after sex, a shellfish that hitches a ride in a fish to complete its life cycle; using body rhythm to warm eggs, a 240km round-trip swim, an 80m glide, a diet of bees, a bird that eats poison but doesn't die and lives to laugh about it, a cave dweller that emerges after years underground to quickly mate and die, a long-necked water 'skunk' that can detect the heart beats of its unborn siblings – some of the extraordinary characters of these forests of many floods.*

Introduction

A SACRED Kingfisher (*Todiramphus sanctus*) alights on a thin, low, exposed branch. Why is it here in the River Red Gum (*Eucalyptus camaldulensis*) forest? There is a combination of reasons. The dead branches on which it perches provide a clear view when hunting. The open forest with its sparse, grassy understorey allows it to view the ground for its main prey of reptiles and insects, and to swoop down grasping them in its strong beak. The numerous tree hollows, which only occur in the very large, old gums, are used for breeding (or alternatively burrows are dug in the steep river bank or a termite mound). Water from the adjacent river is important for drinking and occasional fish for food. It survives here despite competition from the more social and larger Laughing Kookaburra. The life of the forest – its current structure and how it changes over time – is intertwined with the life of Sacred Kingfishers and other resident animals.

Sacred Kingfisher © Stephen Platt.



Approximate distribution of River Red Gum in Victoria.
Source: Victorian Biodiverity Atlas.

Ecosystem outline

IT'S MID-SUMMER. The droning cicadas in the tree tops are deafening. Imagine you are standing on a sand beach on the edge of Australia's largest river (2,508km long), and Victoria's northern border, the Murray. There is a sense of peaceful tranquillity; water flowing by calmly, large trees lining the banks. Now look at the bare sand underfoot and the largely barren strip of soil on the river banks. Plants grow almost everywhere but struggle to live here. The barren riverbank is a clue to dramatic changes that occur here. Just as the ocean beach is a hostile environment for plant life, invaded by the tides daily, so too is the river bank. Each winter, far away in the alpine mountains, snowmelt and rainfall makes its way to the rivers. Flows will increase and water will cover this portion of the bank. The riverbanks will be underwater for months then dry for months. On outer bends, where water velocity is greatest, water erodes soils and undermines the root system of plants. On inner bends, where sand accumulates, seedlings have little chance to establish before being smothered. It is difficult for even the hardiest plant species to survive this regular disturbance. This is the annual rhythm.

The Murray River at Barmah. Note the bare sand banks where nothing grows, the River Red Gums lining the banks and the general appearance of tranquil, slow-flowing water.
© Stephen Platt.

River Red Gum Forest typically has a low, open understorey of grasses with occasional patches of shrubs. © Stephen Platt.

Trees that fall into the river ('coarse woody debris' or 'snags') provide important habitat for wildlife. © Stephen Platt.

Flooded River Red Gum Forest. © Stephen Platt.

Cut-off river channel – 'billabong'. © Stephen Platt.

Rivers also pulse to another rhythm, an unpredictable and yet essential, life-giving one that we call a flood. At flat, low elevations, floods are a natural certainty. On the Murray, significant floods have occurred in 1870, 1890, 1917, 1931, 1952, 1955, 1956, 1960, 1973, 1974, 1975, 1981, 1989, 1992 and 1993, 2000, 2011 and 2012[35] – irregularly but often. In many winters, this can be far from a peaceful place. It can be a scary, dangerous, even deadly place but also a place where rejuvenation happens. During floods, water flows over the banks and out into the surrounding forest where it may lie, metres deep, for months on end, depriving plant roots of essential oxygen, drowning resident, ground-dwelling animals and depriving surviving animals of food and shelter.

Floodwaters carry nutrients, food items and large quantities of eroded soil from the surrounding landscape. They fill depressions adjacent to the river.

Over 7,000 wetlands have been mapped along the Murray River downstream of the Hume Dam.[36] Billabongs (cut off meanders of the river) are unique environments. Some on the Goulburn River, a tributary to the Murray, were cut off from the main stream over 12,000 years ago and, despite siltation, remain over three metres deep.

Subject to the erosive force of water, large, hollow-bearing River Red Gums occasionally fall into the river (colloquially called 'snags' due to their capacity to snag fishing line). Their intertwined branches provide shelter for fish and other species to evade predators, and breeding sites. Post European settlement, thirteen million 'snags' were removed from the Murray River system to facilitate boat travel[37] with dramatic consequences for freshwater habitats.

Floodplain plant species have evolved to withstand not only the force of water, which has nearly half the density of liquid concrete, but immersion underwater for long periods of time.

Cast your eyes around the forest and you will notice that one gum tree predominates. It is covered in smooth white and grey 'gum' bark, which is dark-coloured and rough near the base. This gum has the most widespread natural distribution of any gum tree in Australia. It has relatives in tropical north Queensland and forms single species stands (a monoculture), the largest of which occur on the Murray River in Victoria at Millewa, Gunbower and Barmah (the latter forest was created when the Cadell Fault uplifted a small ridge and so altered the original flow of the Murray River). Its scientific name is derived from the garden of an Italian Count (see 'The Italian connection'). Living for over 500 years and perhaps twice that, it outlives most other species in its community. Over the last six million years, its extent has waxed and waned with the long-term cycles of warm and cool climate, flood and drought. We call it a River Red Gum, the red referring to the colour of its freshly cut wood.

The River Red Gum occupies the rivers, creeks, billabongs, flood runners, channels and anabranches that receive occasional floodwaters, and the border of current and former wetlands at low to moderate elevation, throughout Victoria.[38] A fossil River Red Gum specimen was even recovered from 19m below the low water mark of the Yarra River in Melbourne and radiocarbon dated to 8,780 years b.p.[39] Floods are the key driver of this ecosystem.

River Red Gum derives its name from its red-coloured wood, when freshly cut. © Stephen Platt.

The Italian connection

RIVER RED Gum is connected by its scientific name *Eucalyptus camaldulensis* to an Italian Count, the Count of Camalduli. The tree originally used to describe the species (original 'type specimen') grows in the garden of the Count's country estate near Naples in Italy. The seed from which it was grown had probably been collected on one of the French expeditions to Australia.

In a quirk of taxonomy, it turns out that the tree in the Count's garden is actually not what most people think of as a River Red Gum. Given the widespread, existing use of the name, taxonomists decided to keep the name and nominated a new type specimen from the tree we recognise as River Red Gum.

Water is critical to River Red Gum survival. The energy of each successive flood transports sediments, including sand, that get deposited along the river channel. As time passes, and the course of the river changes, buried sand deposits in ancient river channels (paleochannels), sealed by clay deposited over time, act as reservoirs of water that sustain the thirsty gums through dry periods. Regular flooding refills these reservoirs and keeps these water-needy trees healthy. In summary, no water reservoir, no reliable water supply, no River Red Gums.

The underlying geology of River Red Gum distribution is complex and largely consists of old marine sediments.[40]

River Red Gums extend along watercourses into country so dry that it cannot otherwise sustain trees. But they do not extend far from the watercourses where flood-borne sand has been deposited and the watertable is a shallow two to five metres deep.

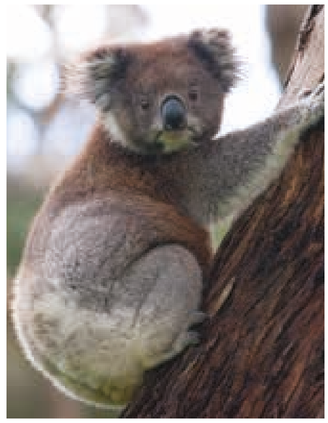
In western Victoria, the original woodlands and forests of River Red Gum were probably formed on ancient wetlands and swamps that are now largely drained.[41]

When a flood comes, River Red Gum seeds get carried, with other debris, to the edge of the floodwaters where they germinate. After floodwaters reach a seed, it remains buoyant for up to 17 days.[42] This is in contrast to most other gums which have wind dispersed seeds that fall close to the parent plant. Unlike many other plant species, the seeds of gums do not remain viable in the soil for lengthy periods and so seed held in the canopy is crucial to regeneration. The timing of flooding affects seed germination success with flood recession in spring being best.

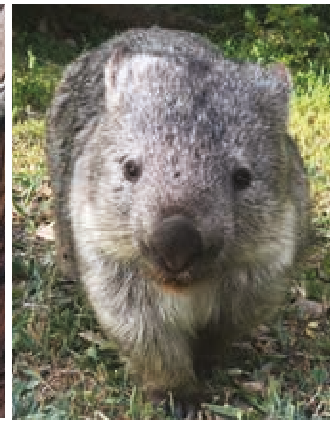
Given the water-hungry nature of this plant, it is not surprising that, following germination, River Red Gum seedlings' roots grow much faster down than their stems grow tall. The race for a reliable water supply is crucial as a return to dry conditions post flood will kill the fast-growing seedlings. It is also unsurprising that seedlings germinate *en-masse* at the floodline where their chance of not drowning and surviving the dry months ahead is greatest. Synchronised germination may assist with limiting the impact of losses due to seed-collecting, and browsing, animals.

The recruitment from these post-flooding, germination events can be seen in the even-aged (similar trunk diameter) stands of trees scattered in patches through the forest marking the high waterline of that flood episode. Look for them and you will see evidence of the extent of floods from years past. Be aware that River Red Gums may also regenerate between floods if conditions allow, so odd-sized trees may also be seen. Over time, the density of trees in these stands will decline as individuals out-compete each other eventually producing century's old, widely-spaced, forest goliaths. Previous logging has removed many of these extraordinary trees but

Even aged trees (same diameter trunk) indicate a recruitment event post flood. Their location indicates the high-water mark of a prior flood. © Stephen Platt.



Koala.
© David Iliff. CC SA 3.0 Unported.



Common Wombat.
© Stephen Platt.

A forest giant. This River Red Gum has withstood centuries of flooding and fire, as indicated by the large fire scar. Lower Ovens River. © Stephen Platt.

The bark of River Red Gums is rough and dark near the base, sufficient to limit damage from low intensity fires.
© Stephen Platt.

some remain (now protected) and you may also see the remaining stumps of former huge individuals.

Studies at Barmah have found that River Red Gums less than 50cm in diameter at breast height have no hollows whereas trees over 100cm have at least one hollow.

The fire risk in River Red Gum forests is low due to the relatively low fuel loads. Most fires are small, of low intensity and infrequent. River Red Gum trees, including juveniles, are relatively sensitive to fire, particularly high intensity fire.[43] They have a short skirt of thicker bark at the base, which is sufficient to limit fire damage from most low intensity fires, but have lost the ability to reshoot post fire from a lignotuber. Younger trees tend to grow together in dense stands which minimises the ground fuel needed to sustain a fire. Hence, fire is not the key determinant of where River Red Gum can grow; flooding, drought and water supply are.

The life history differences between two related animals, the Koala (*Phascolarctos cinereus*) and the Common Wombat (*Vombatus ursinus*), illustrate the relative effects of flooding and fire on wildlife. Whilst wombats burrow and can easily escape a fire that will almost certainly kill a Koala in its treetop, the tables turn in floods where burrows are a liability and a vantage point in the treetops, with food at arm's length, an asset. Hence Koalas are found in forests along the Murray River and other less fire prone areas of Victoria whilst wombats tend to place their burrows in areas that are rarely flood prone.

Plant life

VICTORIA'S RIVER Red Gum communities are naturally lacking in variety of plant species probably as a result of the constant disturbance by floods.

In areas less likely to flood for long periods, they have a tussock-grass ground layer with sedges and rushes in moist areas.

In areas that flood and remain wet – Moira Grass (*Pseudoraphis spinescens*), Common Reed (*Phragmites australis*) and Cumbungi (*Typha orientalis*) grow.

Moira Grass occupies open areas too wet for River Red Gum and is adapted to deep flooding followed by drying. It grows prolifically, helps recycle nutrients and provides habitat and food, as seed, for waterfowl.[44]

Cumbungi prefers stable water levels but shallow enough for its leaves to remain exposed so they can transfer oxygen to the roots.

Common Reed grows where the water levels fluctuate.[45]

In some wet areas, sedges (Cyperaceae family) may be the main ground cover. Patches of shrubs, including bottlebrushes and wattles, also occur in the forest.

Cumbungi was a staple food of aborigines who ate the underground starchy stems (rhizomes) and new shoots. "Roots were cooked in an oven and, after removal of the outer layer, the root was chewed in the mouth until only the fibrous material remained. This was scraped with a mussel shell, then rolled together to make ropes, nets and strings" for fishing.[46,47]

Why don't trees and shrubs take over and shade out the ground cover tussock grasses? In other words, what maintains the patchiness in River Red Gum forests? Three factors are probably important; they are – flooding, fire and grazing.

The frequency, depth and duration of flooding are the main factors determining the pattern of understorey vegetation.[48] Variation in ground elevation, even small increments, benefit one species at the expense of another. Areas that flood regularly will have plants that can withstand immersion, sometimes for lengthy periods of time, such as Moira Grass and Giant Rush (*Juncus ingens*), but may lack trees.

Adult River Red Gums can survive standing in water for a couple of years and even relatively young seedlings of four to six months of age will survive total immersion for several weeks. They have the extraordinary capacity to absorb oxygen through their trunk and stems. So it takes very wet, or very dry, conditions to remove River Red Gum.

Fire also has an influence on the plant species that grow here. It is the fire regime – the intensity, frequency, season and extent of fire – that is most important in determining what grows where. Because of the wet

Moira Grass. © Keith Ward (GB CMA).

Common Reed (foreground) (*Phragmites australis*) © Stephen Platt.

Narrowleaf Cumbungi (*Typha domingensis*)
© Reiner Richter. CC-BY 4.0 (Int).

Australian Reed-Warbler (*Acrocephalus australis*). ©Stephen Platt.

nature of this ecosystem, fire is a relatively unusual circumstance but it does occur. Tussock grasses are very tolerant of fire. Their fine leaves readily burn but the plant survives and rapidly reshoots from ground-level buds protected by its compact form. Fire has a positive influence on where grasses can grow and may 'push back' the tree boundary by killing seedlings.

Shrubs are more sensitive than grasses to fire but they benefit from fire in other ways. For example, bottlebrushes (*Callistemon* spp.) hold their seed in protective, woody cones. Though the parent plant may die in the fire, the seeds will survive, fall to the scorched, ash-covered ground and germinate in the next wet period. Free of competition, they will thrive.

Grazing, primarily by kangaroos and browsing by wallabies, affects recruitment of plants. Grasses can withstand heavy grazing and continuously reshoot. Shrubs and young tree seedlings can be killed if browsed continuously early in life. Today, after long periods of native herbivore and livestock grazing in many of these forests, you may find grazing-sensitive plants confined to the steep, inaccessible slopes of the riverbank.

The density of River Red Gums has increased dramatically – up to nine times – since 1860 primarily due to recruitment of young trees, after felling of large ones, following logging of these forests.[49]

Hence, the patchiness of grassland, shrub-dominated and wetland areas of the forest is maintained by a combination of topography, flooding, fire and herbivory. Trees, shrubs and grasses are all important components of this ecosystem for particular species of wildlife.

Animal life

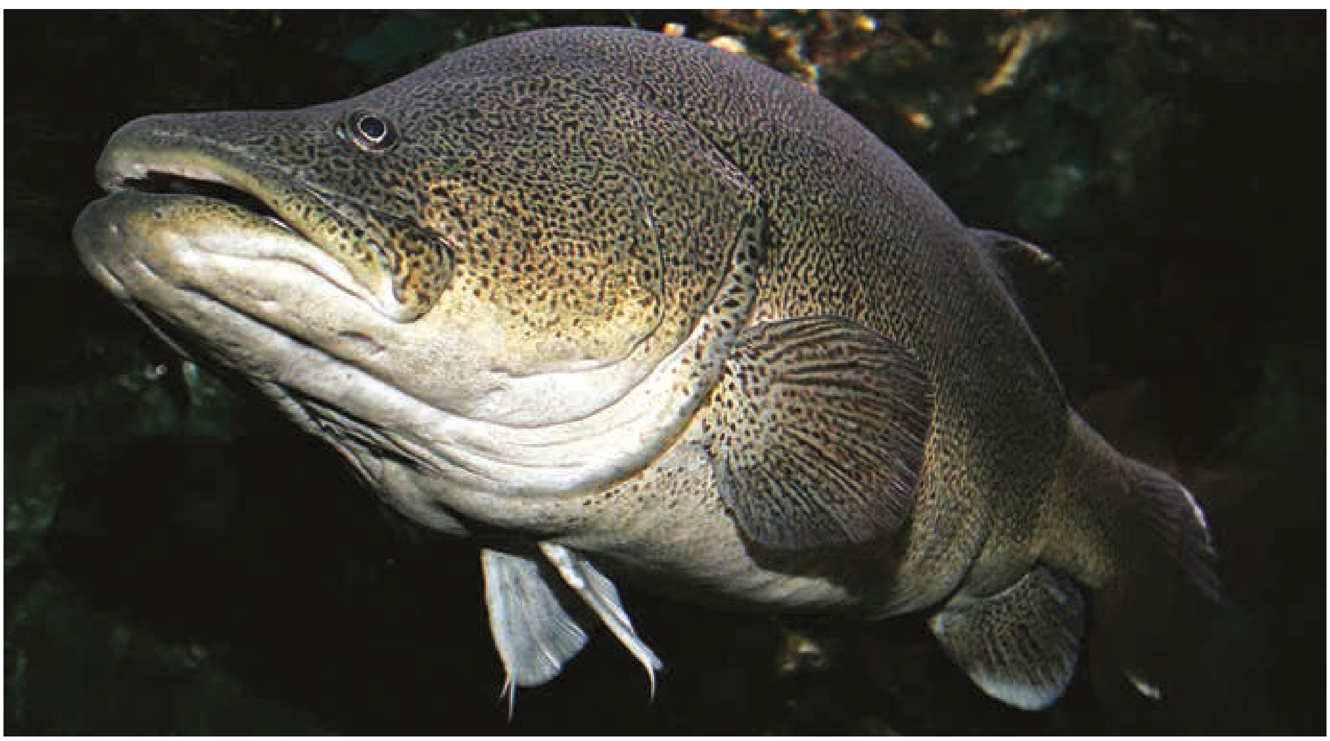
Animals of the water

THE RIVER, with its permanent flow, and the floodplain with its numerous wetlands, provide opportunities for a wide range of aquatic species. The animals that live in the river must survive in a system that continuously moves toward the sea and may occasionally carry deadly, oxygen-depleted blackwater (due to tannin-rich, rotting vegetation; the tannin provides the colour, the rotting vegetation consumes the oxygen animals need to survive). Those that inhabit pools across the floodplain must cope with oxygen-depleted, still water and the risk of their habitat drying up.

There are twenty-two species of freshwater fish in the Murray River and another seven species that migrate between fresh and saltwater (diadromous).[50]

In the dark river waters, amid fallen, entangled tree limbs and roots ('snags') lives a voracious, predatory fish, the Murray Cod (*Maccullochella peelii*). Growing up to 1.8m long and weighing up to 113kg it can grow to be as large as a human – our own river giant. The Murray Cod is our largest native freshwater fish.

The massive size reached by Cod is fuelled by a diet mainly of other fish, up to several kilograms in size, and crustaceans, large and small. They have also been known to eat ducks, cormorants, frogs and snakes. They are the giant 'sit and wait' predator of the waterways and many a smaller fish would have last been seen with its tail fin poking out of a Cod's mouth.



Murray Cod is our largest native freshwater fish.

Murray Cod are mainly found in the river channel or flowing anabranches rather than still, floodplain habitats. They are territorial and spend much of their time around a home location. Sexual maturity is reached at around six years and they can live to at least 48 years of age.

Each spring, adult Cod get the urge to breed and become more active. This sees them set off on an extraordinary migration of up to 120km, usually upstream but sometimes downstream, feeding and searching for a mate. The female Cod is courted by a male and searches for a suitable location to deposit her eggs. Fallen trees provide the branch hollows and other hard surfaces on which to attach her sticky eggs. The 'nest' is prepared and she lays some 100,000 eggs in it. Who would have thought that fish need trees! The eggs will be fertilised then guarded aggressively by the male Cod. After hatching the larvae may stay in the nest for up to ten days before they disperse, drifting with the river flow.

Depositing the eggs upriver makes sense. Rather than being washed out to sea, the young fish fry will move back down the river with the current returning to the river reaches where their parents live. Few will survive the perilous journey.

The parent Cod often return to exactly the same river reaches they occupied before the breeding migration.

In the past, huge quantities of Murray Cod were taken from Victoria's rivers and, at the turn of the 20th Century, concern for the species' future sparked parliamentary inquiries. The register News (Adelaide) 1929 reported:

In [the last] 29 years 26,214,502 lbs (nearly 11,703 tons) [11,915,683 kg] of Murray cod has been eaten by the people of Melbourne. In 1918, the peak year, 2,229,024 lb [1,011,068 kg] was received at the market, but since 1921, when 101,520 lb [499,640 kg] was sent to Melbourne, supply has decreased. Last year [1928] it was only 551,040 lb [249,950 kg].[51]

Fortunately, with greater awareness of the ecology of Cod, today we regulate fishing to sustain their populations.

Jack Brown holds a catch of 24 cod, including both Murray Cod and Trout Cod, near Burrowye, 1939/1940. Source: ARRC.[52]

Sub-adult Freshwater Catfish. © Tarmo A. Raadik.

Adult and underwater 'nest' of the Freshwater Catfish. © Arthur Rylah Institute (fish), Grant Boyle (nest).

All that cats and catfish have in common is the whiskers, although they serve different purposes – one used to judge distance, the other to feel for prey.

The Freshwater Catfish (*Tandanus tandanus*) lives a very different life to the Murray Cod. It primarily inhabits lakes and billabongs, not fast flowing rivers. Living in still waters, these catfish have no need to migrate. In spring the male catfish builds a large, one-metre diameter nest of pebbles and gravel. Courtship involves the male and female circling the nest until the female arches her body, agitates her pelvic fins and releases tens of thousands of eggs into the nest which are fertilised by the male. The male will aggressively guard the nest until the young hatch about a week later. After hatching, the fry leave the nest to take refuge from predators amongst snags and aquatic vegetation. The young catfish feed on plankton and insects. Adults, which live up to eight years and grow to 6kg, consume fish, crayfish, shrimps, caddis and mayfly larvae.[53] While Cod have powerful jaws and articulated mouths to swallow large fish, catfish have whiskers to feel for food which is often invisible in the silt-laden waters it occupies. They are defended by very sharp and mildly venomous spines on their fins.

Parental care and nesting

PARENTAL CARE, as shown by Murray Cod and Freshwater Catfish, is widespread among animals (Mammals 100%, Birds >90%, Frogs 6%).[54] Different faunal groups exhibit varying proportions of male only (69% fish), female only (95% mammals) or biparental care (90% birds). The theory is that increased parental care allows a greater number of young to survive to adulthood and breed. But this needs to be offset against the costs. "Fish dynamically adjust their investment into parental care according to the number of offspring in their brood, past investment, genetic relatedness, and alternative mating opportunities, all of which affect the value of current offspring relative to potential future offspring."[55] Nesting is a form of parental care. Nests aim to keep the young safe from predators that are always on the lookout for a meal of eggs or young.

A mother Godeffroy's Wolf Spider (*Lycosa godeffroyi*) with her spiderlings, which she carries about for their safety.

But fish are not the only inhabitants of these waters. There are three reptilian characters in this story. One has a long neck that some people think resembles a snake. Another has a shell that is big, broad and accommodating. The third is easily recognised by the pale stripe that runs below the jawline and neck. These three turtles live in the same ecosystem. But how? Why do they not compete for food, shelter and other resources with one species being triumphant?

Murray River Turtle. You are most likely to see a turtle on a sunny day basking on a log or other safe perch in the river. Like all reptiles, they need the sun to regulate their body temperature. In winter, turtles go to sleep (torpor) so you won't see them.

Murray River Turtles (*Emydura macquarii*) prefer the main river channel and backwaters where the water is clear, flowing and permanent. They are long-lived and slow growing. Females take 9–11 years and males five to six years to reach sexual maturity.[56] Nests are dug near or up to 40m from the river, usually after steady rainfall in autumn. Sandy sites away from trees and the river are chosen to minimise the risk of nest predation.[57] Female turtles lay 10–15 soft-shelled eggs (the number of eggs increases with turtle size[58]) and up to three clutches in a season, though usually just one. The eggs take six weeks to four months to hatch depending on temperature. On hatching, young turtles scurry to the river where they eat microorganisms and the plants on which they grow. Adult Murray River Turtles eat plants and animals, mainly invertebrates including crustaceans and snails, and fish. Filamentous green algae are an important dietary component.[59]

In contrast, the smaller, carnivorous Eastern Long-necked Turtle (*Chelodina longicollis*) (also called Eastern Snake-necked Turtle) is primarily found in the oxbow lakes, anabranches, ephemeral ponds, river pools and swamps.[60] It eats whatever meat it can find.[61] This includes dead animals (carrion), yabbies, invertebrates, and water-column crustaceans. Terrestrial invertebrates, which fall into the water, free-swimming insects and whole fish are also eaten. Why the long neck? These turtles use their long, muscular neck to strike out at prey as it passes (hence the 'snake-neck'). Their ability to


Eastern Long-necked Turtle. © Katie Howard


A combination of drought and fire most likely ended the life of this Eastern Long-necked Turtle. © Stephen Platt.


Broad-shelled Turtle. © Unsealinglight CC BY-SA

migrate overland (up to 750m), to resist drying out when ponds disappear, and to go into suspended sleep (torpor, aestivation), suits the marginal, variable environments they occupy. Young turtles move between water bodies, particularly during wet weather. It is at this time they are most likely to end up under the wheels of a car. When threatened, Eastern Long-necked Turtles omit a musk smell to deter predators – our underwater 'skunk'.

Broad-shelled Turtles (*Chelodina expansa*) are larger than the other two species and carnivorous. The diet consists of fast-moving prey including yabbies, aquatic bugs and small fish.[62] Their neck also enables rapid striking-out at passing prey. They have a preference for permanent lakes and billabongs.[63] Up to 28 eggs are laid, about 50m from the shore and about 4m above water level, in open habitat with little vegetation.[64] Unlike other species, their embryos can enter suspended development (diapause) allowing them to survive over winter.

Hence, these three turtle species live together by specializing in their use of habitats – river or still water, diet – vegetation or meat, and behaviour.

All reptiles produce eggs and this creates a problem if you live in water because the eggs need to breathe. So, turtles leave the river after rainfall triggers nesting behaviour to lay their eggs in the exposed sand banks and sandy soils along the river channel. These easily-dug areas are ideal places for freshwater turtles to bury their eggs and so hide them from reptile, bird and mammal predators. Clay soils are also sometimes used and this may involve the female making numerous trips to collect water to soften the clay. Leaving the water to lay eggs is a dangerous time for adult turtles. Predators, such as goannas and introduced foxes, can attack the adults or dig up their buried eggs. Up to 95% of eggs may be taken by foxes.

A great variety of freshwater invertebrates occupy the Murray River (430 species of aquatic macro-invertebrate were recorded in one study). They are a critical source of food for many species. Insects (e.g., mayflies, damselflies, dragonflies) are the most numerous but crustaceans (shrimps, yabbies, clams), molluscs (snails and mussels), worms (and leeches) and other primitive species are also well represented.[65] There is even a small freshwater jellyfish (*Craspedacusta sowerbyi*), which grows to 25mm diameter, that has been recorded as far up as the Hume Reservoir and a group of aquatic moths with larvae that live underwater (subfamily Nymphulinae).

Stand knee-deep at the edge of the Murray River, or one of its tributaries, and you may feel the tiny claws of a transparent freshwater shrimp (*Paratya australiensis*, *Macrobrachium australien* or *Caradina mccullochi*) nibbling at the dead flakes of your skin. There is no need to be concerned; they are harmless.

Synchronous hatching and sex determination

TURTLE EGGS hatch at the same time (synchronously). This is thought to help the young hatchlings to avoid predation, the predators being overwhelmed with options as the baby turtles scurry *en masse* from their nest to the water's edge. Synchronous hatching also helps the young to dig out of the nest.

Turtle eggs are subject to differing temperatures, due to their varying depth in the nest, and so develop at different rates (asynchronously). How then do they hatch together?

Unhatched Eastern Long-necked Turtles are able to detect each other's heart beats while they are still in the egg. Amazingly, the less developed embryos can adjust their heart rate to catch up with those that are more developed.[66]

In most species, gender is determined during fertilization. However, in most turtles worldwide, the temperature of the eggs as they develop determines the sex. Higher temperatures favour females, lower temperatures males and fluctuating temperatures both males and females. However, whilst this is generally true, temperature regulation of sex does not seem to be the case with these three Victorian turtle species.[67, 68]

Turtles are culturally significant to Aboriginal people and can be important totemic animals and characters in creation stories. Turtles were also caught and their eggs collected and eaten.

Freshwater shrimp (*Paratya australiensis*).
© Chris van Wyk. CC BY-NC-ND 2.0

Mussel larvae hitch a ride on fish fins before settling to the river bed. Freshwater mussel (*Hyridella* sp.), Ovens River.
© Stephen Platt.

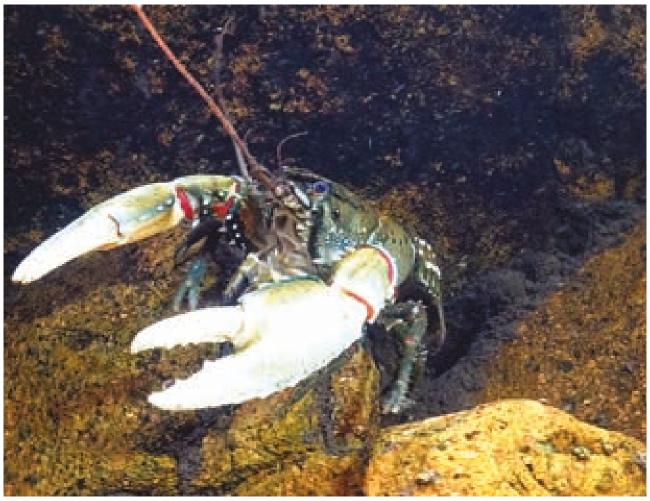
An Azure Kingfisher (*Ceyx azureus*), still wet from its dive, has caught a freshwater prawn. Lower Ovens River.
© Juliet Lowther.

Move to the muddy part of the river, and you may feel the hard, black-shelled bodies of freshwater mussels amid the squishy grey mud underfoot. There are various species. *Alathyria jacksoni* occurs in the main stream channel with flow; while *Velesunio ambiguus* is found in slow or still backwaters and billabongs.[69] Standing vertically, side-by-side and anchored in the mud by a 'foot', mussels extract tiny organisms for food using their gills as filters.

Freshwater mussels reproduce by releasing sperm into the water column which gets taken in by the female as she filters the water. Eggs are incubated inside her shell before the larvae (Glochidia) are ejected. They complete their development by hitching a ride on the fins of a host fish then settle to the river bottom.[70] Hence larval mussels, despite being incapable of swimming far themselves, have solved the perennial problem of having to move against the river's flow or end up out at sea.

Mussels are food for Aboriginal hunters and have been so for 30,000 years.[71] James Dredge, a Methodist preacher and Assistant Protector of Aborigines[72], observed an Aboriginal woman diving for mussels along the Goulburn River in 1840. She remained underwater for two minutes on each dive. Within 15 minutes she collected enough shellfish in a net bag for her whole family.[73] Piles of discarded mussel shells on the river bank can be evidence of Aboriginal feasting on these easily-obtained, reliable, food sources (and perhaps also serve as a marker of where mussel populations can be found).

Murray Crayfish (*Euastacus armatus*), the second largest crayfish in the world (reaching up to 3kg in weight), after the Tasmanian Giant Freshwater Crayfish, also occupy the river and its tributaries. The large white claws of adults stand out in the gloomy water.



Murray Crayfish. © Brett Vercoe. CC-BY-NC 4.0 (Int).

Sulphur-crested Cockatoos. © Jenny Donald. CC-BY-NC 4.0 (Int).

It takes six to eight years before they begin breeding. The female lays up to 1,000 eggs which she carries around in her tail. Murray Crays mainly eat vegetation but will also consume dead animals. They prefer cool, fast-flowing water, deep pools, boulder-rich streambeds, and areas with extensive riparian vegetation.[74] Thus, they are found in the main channel, whilst the smaller Yabby (*Cherax destructor*) is common in billabongs and backwaters. When threatened, Murray Crays spread their legs, extend their body and emit a hiss made by rasping bristles across ridges on their body.[75]

Animals of the land

From the perspective of terrestrial wildlife, the River Red Gum ecosystem provides many opportunities including a bountiful, fresh, water supply, a great variety of hollows for shelter, a food chain built on the nutrients provided by flooding and little risk of fire. It is a relatively easy place to live. The obvious drawback is the risk when floods happen although this can be a bounty to some, such as the many waterbirds. Hence, we find a great many hollow-users, species typical of more arid environments moving here to breed, and good climbers and dispersers at ground level that can flee a flood. Absent are most burrowers, freshwater crayfish being an exception, that might drown.

In Barmah Forest alone 35 mammal, 205 bird, 20 reptile, 10 frog and 28 fish species have been recorded.[76] At least 94 species of reptile are known from the Murray River corridor.[77]

One can hardly visit the River Red Gum forests without noticing the large cockatoos, particularly Sulphur-crested Cockatoo, Galah, Long-billed and Little Corella. When flocks congregate in the evening for bedding-down, and at sunrise, they make a great racket.

Sulphur-crested Cockatoos (*Cacatua galerita*) are long-lived – 20–40 years in the wild and up to 70 years in captivity – intelligent and curious birds. They form large flocks. One or more birds will act as sentries perched on a tree with a good view, warning the others of any imminent danger. They feed on seeds, including grain, roots, berries, nuts, leaf buds, insects and their larvae.[78] These large birds use their beaks to rip apart the wood of shrubs and trees, particularly ageing wattles, to gain access to beetle larvae in the form of fat white grubs. Look out for the tell-tale signs of splintered wood where a cockatoo beak has exposed the former tunnel of a grub (see also page 196).

Sulphur-crested Cockatoos have been reported as eating clay as a means of detoxifying their food. In Victoria, nests are built in large hollows near water. Two to three eggs are laid and both parents share incubation of the eggs and feeding of the young.

The need for cockatoos to drink daily and for safe perches of a night brings them to the river in the evening. The raucous noise we hear is a reflection of their sophisticated social system and communication abilities. They have a voice that can be heard at great distance which helps to bind the flock when it is dispersed among trees. As you walk around the forest in daylight, you will hear the loud screeching overhead as cockatoos warn each other of your presence.

Many birds have plumage that is camouflaged in order to avoid predators. So why are our largest cockatoos white and extremely conspicuous? We don't know but it may be because they have few daytime predators (Powerful Owls prey on Cockatoos at night) and a need to find each other to stay socially connected. Alternatively, white feathers may keep the birds, which often feed in the open, cooler.

Clearing of woodlands adjacent to the river for farming has led to the expansion of some parrot populations, such as cockatoos, and the decline of others including the threatened Superb[79] (*Polytelis swainsonii*) and Regent[80] Parrot (*Polytelis anthopeplus*) which use River Red Gum hollows for breeding but feed away from the river in vegetation being removed for agriculture.

How many eggs in a clutch?

Noisy Miner (*Manorina melanocephala*) nest. © Stephen Platt.

What determines the size of a bird's clutch (the number of eggs laid in a single brood)? Some birds lay a constant number of eggs, others vary within a range.

If the evolutionary objective is to ensure that genes get passed on in future generations then it is the number of surviving chicks that go on to breed that matters. Having one chick is risky, especially if it may die but, given the attention and food supplied by two parents, this risk may be low. On the other hand, in environments where there are good and bad years, having many eggs may mean, in a good year, that occasionally a large number of chicks are raised to adulthood, a distinct advantage over fixed, small clutches. Having many eggs and thus chicks means that the parents must work hard to feed them all and have less time to defend the chicks from predators. If the resources just aren't available in their habitat, then all the chicks may die, a disadvantage of having a large clutch.

Factors predicted to determine clutch size include the amount of food available, which varies with the quality of the bird's territory, the risk of predation to adults and chicks, competition with other birds for resources and other evolutionary influences. Clutch size is known to increase with latitude (increase further from the equator). Also, as day length increases around the globe so does clutch size.

Clutches are consistently largest in cavity nesters and in species occupying seasonal environments, highlighting the importance of offspring and adult mortality.

Limited evidence exists to distinguish between the various possible explanations. It seems that both food availability and the risk of predation of chicks and adults are significant factors.[81,82,83]

The colour of birds' eggs

Why are birds' eggs various colours and patterns? Bird eggs that are out of view in hollows, burrows or deep nests, or in nests the birds sit on continuously, tend to have white eggs (the colour of the calcium carbonate the shell is made of). Birds that build a nest in a tree usually have green or blue eggs and ground-nester's eggs are camouflaged in colours and patterns that blend with the substrate they are laid on so that they are hidden from predators.[84] Egg patterns can also help to distinguish between the eggs of a host bird and a brood parasite.[85] In open situations, egg colour provides sun protection to the developing chick.

The Laughing Kookaburra (*Dacelo novaeguineae*), the world's largest kingfisher (though it doesn't eat fish), is a resident of River Red Gum forests and other forests throughout Victoria. The open ground layer suits the hunting style of these birds. Unlike some other kingfishers which migrate, it is sedentary and lives in the same territory year-round. Listen for the early morning and late evening cacophony of Kookaburra calls, made by an extended family. Their 'laughter' is all about warning neighbouring Kookaburras that this territory is occupied. Their neighbours will often respond in kind along the shared boundary, which may be the river edge or some other landmark. If Kookaburras were not resident, we would not enjoy this remarkable display, as they would have no territory to defend. Territoriality is widespread in animals and often associated with displays of aggression.

Laughing Kookaburra's nest in a tree hollow. © Stephen Platt.

To migrate or not to migrate?

WHY DO some species remain resident and defend a territory whilst others migrate? Migration occurs when resources are distributed seasonally in a broad landscape rather than patchily at a local scale.[86]

Kookaburras look for food primarily on-ground. Their extraordinary eyesight allows them to detect the movement of prey and large bill holds the victim firmly while they knock it on a solid object rendering it defenceless. Despite their reputation as a snake and lizard killer, most of the Kookaburra diet is invertebrates. When eating a snake, Kookaburras don't die of the snake poison because they ingest the snake and its venom proteins are broken down by the Kookaburra's stomach acid. If they were bitten by the snake, they would suffer the effects of the snake toxins like other animals. Kookaburras prefer a large hollow with a floor level with its opening. The young remain in the parent's territory helping to defend it for up to four years. They have a lifespan of around 20 years.

During floods, great congregations of breeding waterbirds may inhabit the floodplains seeking to breed amid the bountiful food supply brought on by the flood. Ibis and cormorant colonies numbering hundreds of thousands have been recorded. Ibis build their nests in beds of Giant Rush and Common Reed, which are flattened into nesting platforms. Cormorants (there are numerous species) nest in nearby trees as do several species of hollow-using ducks – Pacific Black Duck, Australian Wood Duck and Grey Teal.

In summer, on cliff-faced banks of a river, you may see small openings to tunnels excavated by one of two birds, the Rainbow Bee-eater (*Merops ornatus*) or Spotted Pardalote (*Pardalotus punctatus*). They lead to a nest chamber a metre or so into the soil. Burrowing on steep slopes provides some protection from predators, including goannas and Yellow-footed Antechinus[87], and protection from climatic extremes (in Queensland, Cane Toads[88] and Dingo (*Canis lupus dingo*) are major predators of Bee-eaters; the toads invade the burrow and eat the eggs and chicks). Rainbow Bee-eaters migrate from islands to the north of Australia to breed as far south as Victoria. They may nest singly or colonially. It takes 5–10 days to construct the burrow. Pairs of birds, or trios (45% in one study, the couple plus an unpaired male), attend the nest.

These flighty birds are very mobile and use up lots of energy. Hence, they must eat a lot. Bee-eaters consume several hundred bees in a day along with other flying insects. You will encounter them in summer as, in winter, when the steep banks of the river may be below water and not available as a nest site, they have migrated to northern Australia.

Grey Teal (*Anas gracilis*) occupying a hollow. © Stephen Platt.

Rainbow Bee-eaters outside their tunnel nest entrance on an exposed river bank. © John Robert McPherson. CC SA 4.0 (Int.).

Spotted Pardalote (male and female) pair beside their nesting tunnel on the Yarra River (18km NEE of Melbourne). © Stephen Platt.

A juvenile White-bellied Sea Eagle patrols the Murray River at Barmah. © Juliet Lowther.

Eastern Grey Kangaroos blend into the grey and brown background of these forests. © Stephen Platt.

Eastern Ring-tailed Possum. © Rick Tinker.

An Eastern Ring-tailed Possum's ball-shaped, stick 'drey' in dense shrubs. Once you learn to spot them you will realise how common they are. © Stephen Platt.

Mammals also frequent the River Red Gum Forests. Most are nocturnal. Night-time activity probably helps to avoid daytime visual predators and maximum temperatures. However, there are plenty of hazards during the night including predation by large owls.

Their ball-shaped, black droppings composed of digested grass are easy to see scattered on the ground but not so the animal they belong to. When standing still, an Eastern Grey Kangaroo (*Macropus giganteus*) is well camouflaged and blends into the forest of grey tree trunks. Nocturnal and crepuscular, meaning active in twilight at the start and end of the day, they form open-membership groups. Daytime is spent resting in woodlands. Eastern Grey Kangaroos feed mainly on grasses and are our largest native grazing animals, the marsupial equivalent of deer, guanaco, antelope and zebra on other continents. In contrast, the Black-tailed Wallaby *(Wallabia bicolor*), seen commonly in the shrubby forests of Victoria, is primarily a browser feeding on the foliage and fruits of low shrubs.

Kangaroos are efficient breeders and numbers increase with increasing grass availability. Their natural predator, the Dingo, is all but absent. This, and the abundance of food provided by agriculture, has led to very high kangaroo numbers in some areas. Adult females are continuously pregnant and are able to freeze development (embryonic diapause) of the next joey until the previous one leaves the pouch. Like all marsupials, the young are born at an early, undeveloped stage. A newborn joey weighs less than a gram and will suckle in its mother's pouch for 9 months before leaving it permanently. Full independence occurs at about 18 months.

Large, male Eastern Grey Kangaroos weigh 66kg and stand two metres tall. They can travel at up to 64km/hr. Kangaroo numbers are relatively high in these forests because of the mix of wooded areas for shelter and open areas for grazing.

As night begins to fall, some resident mammals begin to waken in their hollows. Soon after dark they will venture out. Listen and you may hear a quiet trilling that indicates a Eastern Ring-tailed Possum (*Pseudocheirus peregrinus*) emerging from its ball-shaped drey, a daytime nest made of sticks and leaves in a dense shrub thicket; or a louder guttural sound, its larger relative the Common Brush-tailed Possum (*Trichosurus vulpecula*) warning off a rival intruder after exiting its tree hollow. During the night, and sometimes day, the rasping 'snores' of male Koalas may also be heard.

Listen very carefully and you might also hear distant puppy-like yaps – the Sugar Glider (*Petaurus breviceps)*. During the day, look out for where it has chewed a wattle tree until it bleeds sugary sap, a favourite food and source of carbohydrate, especially in winter. Sugar Gliders live


A Sugar Glider tail lying on the ground after it has been removed by a predator, most likely an owl. Note the white tip.


Sugar Gliders live in family groups in a tree hollow and will readily take to artificial nest boxes. They construct cup-shaped nests made of eucalypt leaves.


Sugar Gliders feeding on the sugary sap of a tree.


Two-week-old juvenile male Sugar Glider.

in large family groups of up to twelve related individuals. Their nest is made of neatly arranged gum leaves in a hollow with a narrow entrance, just big enough to squeeze through (~35mm). This means that no predator bigger than the entrance can get in. Although only 30cm in total length and weighing less than 180g, the Sugar Glider has been recorded making a single glide across the Murray River, a distance of 80m (about half the length of a football oval). They best move quickly because they are at risk of losing their life to a forest owl. If that happens, one of the owl's first actions will be to snip off the glider's tail which will fall to the ground as evidence of the event. Daytime also has its hazards. I have seen a Sugar Glider make a daylight, life-saving leap after being routed by a group of Pied Currawongs. They pursued the glider mid-flight and remained on watch outside the hollow it escaped into.

Sugar Gliders mark their territory with scent to warn other colonies to stay away. Their large eyes and good looks appeal to humans but there's another side to their character. Recently, researchers investigating the decline of the Swift Parrot (*Lathamus discolor*) discovered that, on mainland Tasmania where Sugar Gliders are introduced, over half (51%) of nesting female parrots were preyed on by Sugar Gliders.[89,90]

Bats are common in the River Red Gum forests. After dark, listen and you may hear the echo location 'clicks' used for navigating through trees and locating prey, such as a moth. The White-striped Free-tailed Bat is the only microbat with calls within the range of human hearing. Were you to have a bat detector handy, which can 'hear' higher frequency calls than human ears, you would notice just how common microbats are in the forest around you at night.


White-striped Free-tailed Bat (*Austronomus australis*).▶

Female Lesser Long-eared Bats (*Nyctophilus geoffroyi*) and Gould's Wattled Bats (*Chalinolobus gouldii*) roost in large, old or dead River Red Gums. Individual bats use more than one roost site over time to both avoid predators and promote hygiene. They travel long distances (~13km) to their feeding areas in adjacent farmland. The Southern Myotis (*Myotis aelleni*) forages over water, catching aquatic insects and small fish (see p223). Twelve species of insectivorous microbat and one flying fox have been recorded from Barmah Forest.[91]

Inland Carpet Pythons (*Morelia spilota*) and Lace Monitors (*Varanus varius*) (our second largest terrestrial carnivore after the Dingo), hunt in these forests. Carpet Pythons favour the drier Box (eucalypt) ridges[92], are slow-moving and often active at night, looking for sleeping, warm-blooded animals which they detect using heat-sensory pits in the lower jaw. They also use ambush tactics and may wait for weeks before catching prey, which they kill by strangulation, up to the size of a wallaby. Female pythons mature at about three to five years of age (150cm) and grow to 2.5–3.0m. Up to 30 eggs are laid in hollow stumps, under bark or in dense vegetation. The eggs stick together to form a single clump that the female coils around. She uses rhythmic movements of her body to produce heat for their incubation. The young snakes feed on small lizards.

The semi-arboreal Lace Monitor uses tree hollows, hollow logs and animal burrows as den sites. They are active during the day and range over large areas up to 400ha. The diet includes mammals; birds, their eggs and young; arthropods and carrion. In a study of Lace Monitors in south-eastern Victoria, Eastern Ring-tailed Possum comprised two thirds of the diet and Black-tailed Wallaby (*Wallabia bicolor*), as carrion, most of the other third.[93] Predation on possums increases after fire.[94] Male monitors participate in ritualised combat to secure females. In southern Victoria, Lace Monitors will excavate termite mounds in which to place up to 19 leathery-shelled eggs. The termites quickly re-seal the opening. Their activities inside the mound provide the heat and humidity for incubation. In the following spring, after around 300 days, their mother will return to excavate the mound, release her young and perhaps lay another clutch.

With so much water in the forest there are also many frogs. The large Peron's Tree Frog (*Litoria peroni*) has a distinctive call that gives it the nickname of Maniacal Cackle Frog. They are agile climbers and hollow users and have the ability to change colour rapidly. Unlike any other Victorian frog, they have a cross-shaped pupil. From spring to summer, calling males seek to attract females to still waterbodies where they will mate and lay their eggs.

If we now consider the smaller critters, the terrestrial invertebrates, though largely concealed to the human

Inland Carpet Python (*Morelia spilota ssp. metcalfei*).

Lace Monitor.

The cackles of Peron's Tree Frog can often be heard emanating from its hiding place in a tree.

eye, they are nevertheless numerous. When two River Red Gum canopies were sprayed with insecticide, 6,666 invertebrates of 450 species were collected.[95,96] They comprised species that feed on River Red Gums, species that feed on other invertebrates and others. Some bite off chunks of leaf, others eat the leaf from the inside and yet others use chemicals to induce the leaf to produce more cells for their larvae to eat.

Larvae of the Rain Moth (*Trictema atripalpis*) (Giant Ghost/Swift Moth), also known to fishermen as 'bardi grubs', feed on the River Red Gum roots. The brown casings they leave behind on emergence are often seen partially protruding from the ground under the tree canopy. Moths emerge post rainfall, hence the common name 'Rain Moth'.

Sphallomorpha spiders prey on ants moving up and down the tree trunk. Wasps lay eggs in the larvae (caterpillars) of other species, which provide food for their young on hatching. There are twenty-two species of invertebrate that parasitise the larvae and eggs of just one other species, the Gum Leaf Skeletonizer (*Uraba lugens*). Booklice eat fungi growing on the tree. Bird nests provide habitat for ticks and lice. On the forest floor, small beetles feed on the moulds growing on decaying phytofall.

Floods affect the ground fauna. As you might expect, species move up onto trees and shrubs to avoid drowning. Termites tend to be found in areas above the floodline. Some ground-dwelling ants even move their pupae from decaying wood nests to under bark on tree trunks. As floods recede, wolf spiders increase as they feed on the dead bodies of species that died during the flood.

Every so often these forests are plagued with caterpillars. Gum Leaf Skeletonizers march up tree trunks in long chains, consume the leaf canopy and, if you are unlucky enough to be camping beneath them, as I have been, can be so numerous that they cover all surfaces and fall from overhanging branches into your cup of tea. Cup Moths can also occur in plague proportions. These sporadic irruptions, though dramatic at the time, cause no long-term damage to the forest ecosystem. In fact, they are probably a bounty for many predators. Outbreaks occur when there are no floods. Floods decrease overabundant populations by reducing the availability of pupation sites and increasing a fungal disease.[97]

The invertebrate fauna is constantly changing. At a location, species change over seasons and years, between night and day, as habitats mature and in response to disturbance by fire and flood.

Rain Moth. © Arthur Chapman. CC BY 2.0.

Rain Moth casing left behind after emergence. © Stephen Platt.

Gum Leaf Skeletonizer. © Reiner Richter. CC.

The Gum Leaf Skeletonizer is also known as the Mad Haterpillar due to the retention of the head portion of its skin each time it sheds. © Ken Walker. CC-BY-NC-SA 4.0 (Int).

Skeletonizers on the march up to the canopy of a wattle and massed on the ground, Lower Ovens River, 4 June 2010.
© Stephen Platt.

Newly emerged adult Green Grocer Cicada (*Cyclochila australasiae*) drying its wings. © Neil Skene. Public domain.

In summer, the River Red Gum forests throb with the drone of male cicadas permeating the air. At 120 decibels, these are the loudest insects on Earth.[98] Cicadas sing in chorus, which makes it difficult for a predator to locate an individual. Unlike crickets, which rub their wings against their body (stridulate), cicadas make this loud noise by pulling their box-like body in and out to produce a continuous stream of clicks. This above-ground stage in their lifespan, which involves searching for a mate, is short and full of danger as birds and other wildlife hunt these large, conspicuous insects.

Most of the cicada's life is spent underground. Female cicadas have a saw-edged, egg-delivery tube (ovipositor) that is used to slice open the bark of a twig in the tree canopy. After mating, eggs are laid into the slit and, on hatching, the newly emerged nymphs plummet to the ground where they immediately burrow. The next two to five years of their life are spent up to 2.5m underground in a chamber sucking on the sap carried in the roots of their tree host. Eventually they will re-emerge through a tunnel and climb aloft a sturdy stem or tree trunk. Back in the sunlight, they will cast off their external skeleton for the final time and, with newly developed wings, fly off to find a mate, thus completing their life cycle and bringing their love songs back to the forest. If not the insect itself, you can usually spot their cast-off external skeleton hanging on to vertical surfaces throughout the forest. Cicadas are a food source for many forest animals.

Discarded 'exoskeletons' (or 'exuviae') show where adult, winged cicadas have emerged. The exoskeletons will disappear but what happens to them? © Stephen Platt.

The sugary coating (lerp) made by a psyllid bug. © Stephen Platt.

The Common Bagworm Moth (*Psyche casta*) is often seen attached to the rough bark furrows of a eucalypt. © Stephen Platt.

River Red Gum leaves may be covered by colonies of small (few mm), white 'tents' called lerps made of crystallised honeydew. Under this covering is a small sap-sucking bug called a psyllid (pronounced sil-lid). Lerps come in many designs including fairy-floss fluffy, fan-shaped and conical. They are a popular food source for birds, such as pardalotes and the Noisy and Bell Miner (*Manorina melanocephala, M. melanophrys*), which harvest the cover but leave the insect to make a new one. When abundant, aborigines also feasted on their sugary content.

In conclusion, Victoria's River Red Gum forests are occupied by animals that are attracted to their abundant water, their open structure and abundant hollows; and that can survive in this regularly disturbed, flood-prone environment.

Where to see this ecosystem

- Barmah National Park
- Gunbower National Park
- Public land along the Murray River and the lower reaches of the Goulburn and Ovens Rivers.
- Hattah-Kulkyne National Park
- Murray-Sunset National Park
- Grampians National Park

Excellent maps of public land are available from the VEAC River Red Gum Forests Investigation.[99]

Chapter cover: Two large, old River Red Gums that germinated at least 100 years previously stand amid a recent generation of thin-trunked juveniles indicating a recent flood some 5–10 years ago. In the background is a distinct browsing line below which foliage is eaten suggesting a significant kangaroo or cattle population. On the foreground gum is a chainsaw scar. There are no obvious fire scars on the larger trees.

A brilliant decision

IN 1881, public land along the Murray River was reserved for us all to enjoy as shown in the notice published in the Victorian Government Gazette Feb 11, 1881, p484.

LAND PROPOSED TO BE PERMANENTLY RESERVED FROM SALE.

IN pursuance of the provisions of *The Land Act* 1869 (33 Vict. No. 360, § 6 and 8): Notice is hereby given that it is the intention of the Governor in Council to reserve from sale, *permanently*, for public purposes, the lands hereinafter described, viz. :—

The following Notice was gazetted 1° on 11 February, pursuant to Order of 7 February 1881.

1. *River Murray.*—Along the left bank of the River Murray from its source to the point where the boundary-line between the colonies of South Australia and Victoria intersects the same, all land, the property of the State, within a distance of three chains from the ordinary winter level of the river as confined by the said left bank, and as regards the several ana branches leaving and re-entering that river on its left bank, the beds of the same, and all lands of the State within a distance of two chains from either bank of the said ana branches measured from the winter level of the water confined within the said banks.

Of the approximately 170,000km of river frontage in Victoria, 18 percent is publicly owned. Crown water frontages, as they are called, are accessible to the public for recreational uses.

Nature and the law

THE FIRST official action to protect native wildlife in what was to become Victoria was the General Order proclaimed by Lieutenant-Governor David Collins on 30 November 1803 for his settlement at what is now Sorrento. The order prohibited the taking of birds' nests and their contents.[100]

Early records of Victoria's wildlife – Horace William Wheelwright (1815–1865)

HORACE WILLIAM Wheelwright came to Australia during the 1850s gold rush and became a professional game shooter supplying the Melbourne market. The book he subsequently wrote about his Australian experiences, "Bush Wanderings of a Naturalist", is an important source of information about the natural history of the area around Melbourne in the 1850s. For example, he wrote that "the Magpie Goose, or Tree-goose (ongak) is the common wild goose in this district, and, as far as I could learn, is the only common wild goose peculiar to Port Phillip." Magpie Geese are now considered near threatened in Victoria. They have largely disappeared from the State along with their shallow wetland feeding and breeding habitat.

Magpie Goose.

Wheelwright makes numerous comments on Aboriginal use of wildlife such as recording for the Opossum (Common Brush-tailed Possum) "The blacks score the inside of their skins with a kind of hieroglyphic, and I have seen one marked representing a map or chart" (on p45).

Of the "Wild Dog, warrigal, or dingo", he notes "it is met with in all the thick forests, deeply-scrubbed gullies, in belts of timber bordering on the large plains, and in patches of tea-tree on the plains themselves, throughout the whole country, of course commonest in the most unfrequented districts, and is the only large wild animal of prey at present known in Australia."

Wheelwright reminds us of how much what we experience today differs from how it was in the period prior to European settlement.

A group of Aboriginal men in possum skin cloaks and blankets in 1858 at Penshurst, in Victoria's western districts.

Photo: Antoine J. Fauchery. Source: Museums Victoria.

A land of gliding possums

A land of gliding possums

LARGE VEGETARIANS, fast moving hunters and tiny honey-eaters – these otherwise diverse possums share one characteristic – an ability to glide. Gliding is an adaptation that allows the animal to avoid predators lurking on the ground or in a tree and to gain efficiencies when moving about the forest to feed. It is obviously a very useful strategy, having evolved in so many species on multiple continents. It's also an indication of the precarious existence of these animals. They live in a world of predators, primarily large forest owls. During daylight these gliders will be safely encased in a tree hollow but even then, they must take care to avoid predation.

Greater Glider (*Petauroides volans*) is the giant of the gliding possums. It occupies high altitude, tall, wet, old-growth mountain forests where it feeds on leaves, buds and flowers of eucalypts, favouring Narrow-leaf Peppermint (*E. radiata*).[101] Their bright eye-shine in torchlight helps with detection. Climate change, particularly increasing dryness and its associated fires, may be the cause of the recent contraction in their range.[102] They are listed as 'vulnerable' to extinction.

The mid-sized Yellow-bellied Glider (*Petaurus australis*) lives in a wide range of foothill and coastal forest types characteristically of mixed-species and containing smooth-barked eucalypts. The distinctive V-shaped incisions these gliders make in the bark of trees, to feed on sap, are a sign of their potential presence. The Gliders focus on an individual tree perhaps because of the quality of its sap. The tree may also serve as a territorial boundary marker. The loud 'shriek-gurgle' sound they make after exiting their den, about half an hour after dark, is unmistakable. Yellow-bellied Gliders live in small family groups and can glide up to 150m.[103] Their food includes invertebrates, eucalypt sap, nectar, pollen, manna and honeydew. They sleep in hollows high up in eucalypt trees.[104]

In Mountain Ash forests of the Central Highlands in Victoria, Greater Glider and Yellow-bellied Glider occupy old-growth forest, as does the Sooty Owl (see page 208).[105]

Small, light and agile, Sugar Gliders (*Petaurus breviceps*) live in tree hollows and forage in family groups. In autumn and winter, they feed mainly on wattle exudates and gum tree nectar. In spring and summer, they primarily eat insects.[106] Sugar Gliders may be heard after dark making their characteristic soft puppy-like yap – yap – yap.

The threatened Squirrel Glider (*Petaurus norfolcensis*) lives in River Red Gum forest and dry woodlands but rarely overlaps with the slightly smaller, and much more common, Sugar Glider which it resembles. Squirrel Gliders may be encountered after dark sitting quietly

Greater Glider. © Josh Bowell. CC BY 4.0.

Yellow-bellied Glider. © Tim Bawden CC-BY-NC 4.0 (Int).

Yellow-bellied Glider feed tree at Lake Cobbler, 57km east of Mansfield. Note the V-shaped incisions in the bark a few metres above ground level. © Stephen Platt.

Sugar Glider. © Chris Cook.

Squirrel Glider. © Tim Bawden. CC BY 4.0

Feathertail Glider. © Doug Beckers. CC SA 2.0 Generic.

in a wattle feeding on sap or in a tree canopy hunting invertebrates or feeding on pollen.

Finally, the tiny Feathertail Glider (*Acrobates pygmaeus*) is the world's smallest gliding mammal, weighing about 12 grams. It lives in a range of forest types and is capable of climbing a pane of glass. Feathertail Gliders feed on nectar, pollen, and arthropods such as moths, ants, and termites. They are arboreal, and although occasionally descending to the ground to forage, they spend as much as 87% of their time over 15m above ground, particularly in gum trees. Like all gliding possums, they are nocturnal, spending the day resting in nests in tree hollows lined with leaves or shredded bark. Feathertail Gliders are social animals, and up to five may share a single nest, especially during the breeding season.[107]

Not all possums are gliders. Common Brush-tailed, Mountain Brush-tailed, Common Ring-tailed and Leadbeater's Possum are not built for gliding as they are relatively heavy and lack a gliding membrane. Leadbeater's Possum prefers a structurally dense forest, which allows rapid movement between tree canopies without the need to glide.

To find gliding possums, listen for their distinctive sounds after dark or look for their reflective eyes using red torchlight. Witnessing a glide is a wonderful experience.

Sugar Glider incisions on this gum tree are made to access the tree sap, a source of carbohydrates.
© Stephen Platt.

A character shaped by fire

Vivid flowers of several species brighten this picture but what else can we see in this image that tells us what has happened here? Steel's Creek, 2010.

© Stephen Platt.

A character shaped by fire

***FIRE FROM** water, trees tougher than aluminium, what volcanoes gave to plants, born from a wooden casket, mysterious mushrooms and the 'stone-maker', counting time with charcoal. This chapter looks at a major ecosystem disturbance – fire – an event that upends the rules of the contemporary ecological game creating new winners and losers, at least for a time. Fire – which to humans is both fear inducing and hearth-warming – has had a significant role in the history of life.*[108]

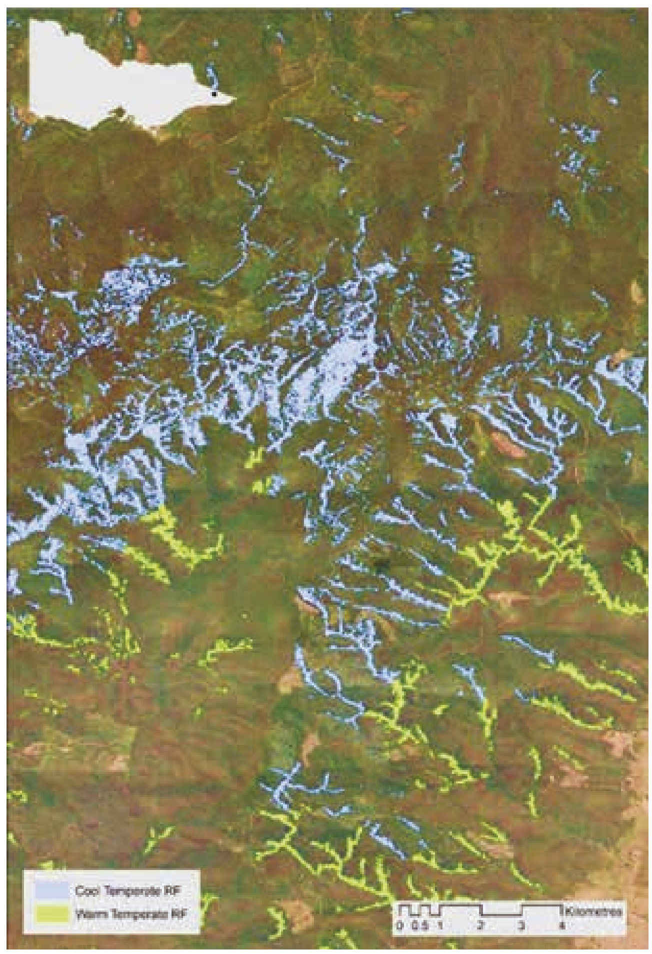
Introduction

IT IS ironic that, in order to have fire, you need to have plenty of water. Water in the form of rainfall is the main driver of plant growth. More growth means more potential fuel for a fire. You also need dry, hot summers. Heat dries out the vegetation and also creates the conditions for lightning storms. Lightning is the match that starts fires. Southern Victoria has all the above and that is why it is one of the most fire prone regions on the planet.[109]

Victoria today is a land of gum trees but it wasn't always so. In the past, when Victoria's geographical position was further south and connected to the supercontinent Gondwana, wet coniferous forests, the precursors of today's rainforest, were much more widespread. So how did eucalypt forests become so dominant?

The main cause of rainforest decline was fire, fire that raged across the landscape when conditions got hotter and dryer as Australia, after breaking off from the Gondwanan landmass, drifted northward. Unlike most rainforest plants, the eucalypts had evolved to survive fire and flourished. Their extraordinary ability to reshoot after a fire, from 'epicormic' buds protected beneath bark, may have originated from ancestors that grew in the vicinity of Gondwanan volcanos 60 million years ago. Molten lava was hot enough to ignite wet rainforest vegetation and to create a space in which fire-adapted species could evolve.[110,111] We can see similar processes occurring in caldera habitats of Papua New Guinea today. Regular exposure to fire selected for the remarkable, fire-adapted traits of eucalypts. Today we find remnant stands of rainforest in fire refugia; usually steeply-sided, wet valleys where fire rarely penetrates.

Lightning is the main source of fire ignition. Lightning strike near Canberra, ACT, on 16 January 2003. © Chris Arndt.



Fire assisted the rise of eucalypts and confined rainforest to fire refuges. This map indicates the distribution of Cool and Warm Temperate Rainforest in Gippsland. © DELWP. CC 3.0 (Aust.)

Fire is a major disturbance in most of Victoria's ecosystems and shapes what you see in the bush. © Don Pratt.

Woody (serotinous) seed capsules, such as these, protect their enclosed seed until a fire has passed then release the seed onto the soil surface ready to germinate with the first significant rainfall. Storage of seed in woody capsules in the canopy of trees and shrubs is widespread in the Victorian flora and an adaptation to fire and seed predators. *Hakea* fruits (top left), she-oak cones (below), and banksia cones (top right) are examples of fire-resistant seed storage vessels.
© Stephen Platt.

The presence of rainforest at a location is evidence that severe fire has not occurred there more often than once in several hundred years (the time taken for rainforest recovery).

Unable to run, plants must withstand fire temperatures of up to 700°C, enough to melt aluminium (melt point 660.3°C).

Immediately after a fire, it can seem like everything is dead but that is not the case. In ecosystems where fire is a normal occurrence, plants and animals have had to adapt to it. Fortunately, the heat of fire does not penetrate far underground. Root systems remain unaffected and alive. Growth buds protected beneath the soil or under bark usually survive the fire. Buried seeds, and seeds protected by woody capsules, remain viable. Not only that, their seed dormancy may be broken by the effects of fire, including by heat, smoke and increased light. After-fire conditions, including abundant sunlight, reduced competition from other species and an increase in available nutrients in the form of ash, lead to an explosion of plant growth driven by these living elements. In spite of what is before your eyes in the aftermath of a bushfire, have no fear that regeneration will occur, it has done so for tens of thousands of years.

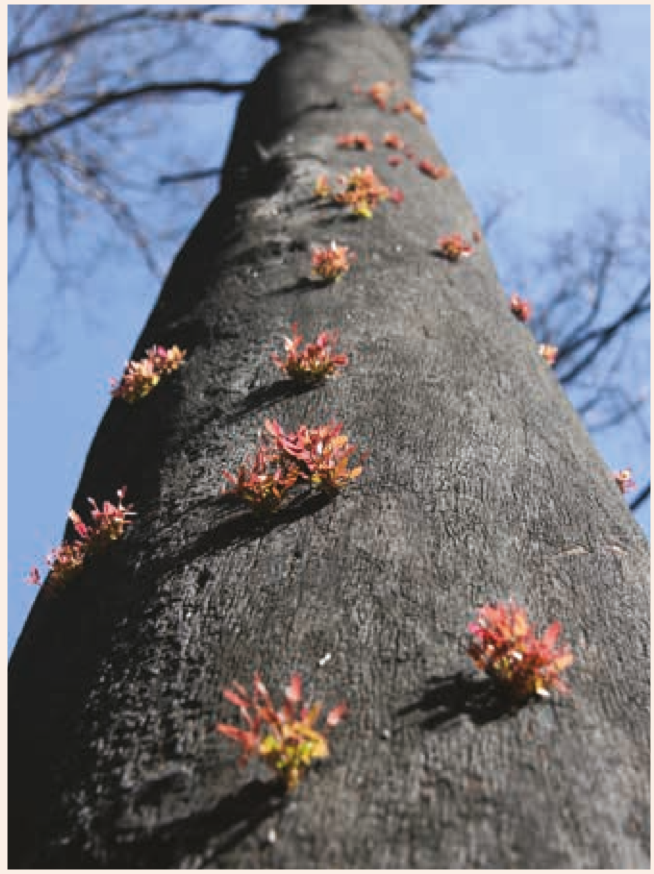
Most species are adapted to survive fire

WE KNOW that fire has been a part of the Victorian landscape for a very long time because of the adaptations we see in so many species.

Some plants **resprout** from buds protected beneath the bark or just beneath the soil surface. Other species regenerate *en masse* from seed. These '**obligate seeders**' can be vulnerable if a second fire occurs before they reach sexual maturity (i.e., when they produce a new generation of seed). The ratio of obligate seeders to resprouters varies among ecosystems. In one study, rocky outcrops had a 90:10 ratio whilst grassy forests had a 19:81 ratio.[112]

This stand of Mountain Ash, an obligate seeder at Wallaby Creek catchment, Kinglake West, was killed by the 2009 bushfires. Dense regeneration is by seed. A second intense fire, before the seedlings start to produce seed at around 15 years of age, could dramatically alter this ecosystem by killing the immature seedlings. In normal circumstances this is unlikely because the dense regeneration retains moisture that thwarts another fire. Climate change may reduce that natural protection. © Stephen Platt.

Despite initial appearances, most plants are able to survive intense fire. Post-fire regeneration, Mt Bishop track, Wilson's Promontory. 2009, 2010, 2019 sequence.
© Stephen Platt & Lynden Costin.



Epicormic shoots emerge after the intense 2009 Black Saturday bushfires burnt this tree near Walhalla. They will provide immediate photosynthetic relief to the plant allowing it to produce energy for growth. Over time, a leafy canopy will re-establish and the epicormic leaf bundles will drop off.
© Stephen Platt.

Most plants in Victoria, such as those pictured, are able to resprout after fire. The species most vulnerable to altered fire regimes are those that rely on seed alone. © Stephen Platt.

◀ Mountain Ash seedling germination following the 2009 Black Saturday bushfires. The nutrient rich ash bed and reduced competition from adult plants favours rapid seedling growth. © Stephen Platt.

Given the losses often reported in the media, it may come as a surprise that most species and populations will survive bushfire. Not all individuals escape but the forebears of today's wildlife have had to survive previous fires and must have strategies to do so or they would not be here now. Animals escape into burrows, tree hollows, rocky areas, unburnt patches, wetlands and waterways, and flee fire by running, slithering, hopping or flying. Many invertebrates have underground life stages that place them out of harm's way.

Nevertheless, fire can be a major threat to plants, animals and ecosystems when significant changes to the fire regime occur, as with climate change, and to threatened species already struggling to survive before a fire adds to the pressures they already face.[113]

Different ecosystems have different fire tolerances. Some cope with lots of fire, others are intolerant. In particular, tall wet forests and rainforest can only tolerate very infrequent fire. To survive, fire intolerant species 'retreat' to positions in the landscape that are less likely to experience severe fire. Alpine Ash (*Eucalyptus delegatensis*) takes refuge at high altitude. Other species find refuge in deep valleys, rocky areas, atop sand dunes and near waterbodies.

This wombat burrow has been 'tidied up' post fire and its occupant's footprints can be seen in the surrounding ash and sand indicating that it is alive. © Stephen Platt.

The leaf bases of Grass Trees can provide shelter from fire to small animals, like this Marbled Gecko (*Christinus marmoratus*). © Richard Lovett.

This Stone-maker Fungus (*Laccocephalum tumulosum*) is fire-adapted (pyrophilous). It fruits within 24 hours following a fire in order to distribute its spores. They settle on newly fallen logs and so restart its life cycle. The 'stone' refers to an underground fungal mass it produces. Fire-adapted fungi are a short-term food source for some animals. Robertson Gully, Marysville.[114] © Stephen Platt.

Fire regimes

Fire is essential for the health of many ecosystems. The fire regime – intensity, frequency, season, and extent – of fire is a key determinant of which species can survive at a location. The interplay of these fire regime components, as well as successive fires, creates a mosaic across the landscape. While we tend to focus on the effects of the most recent fire, there is a 'hidden mosaic' of fires that occurred before it. Thus, when you are walking through the bush remember that every patch has a fire history. That history might be the reason that, when all other factors (soil, water, sunlight) seem equal, there is a distinct change in vegetation (e.g., shrubs to grasses).

Rainforest persists in the absence of fire. Where fire penetrates at the margins, eucalypts infiltrate only to die out, as this stump testifies, once they pass their lifespan *if* no other fire occurs. © Stephen Platt.

A fire mosaic in the Mallee consisting of areas that in recent times are unburnt, have burnt once or multiple times. © Kathryn Schneider, DELWP. CC 3.0 (Aust.)

A very intense fire at Marysville 2009 (left) has consumed most vegetation but within a year (right) it was impossible to pass through the regenerating plants. © Stephen Platt.

When talking about fire, there is a difference between severity and intensity. The former relates to how much damage was done, the latter to the heat of the fire.

Fire intensity is influenced by the amount of fine fuel that accumulates, allowing for decomposition and differing rates of production over the life of the forest. Many gum trees add to the fine fuel by shedding bark and through leaf fall. Animal species, such as Superb Lyrebirds, through raking over phytofall in their search for food, aid decomposition by invertebrates, fungi and bacteria. Their activity can decrease the amount of surface fuel by up to 25%[115], and disrupt fuel connectivity, so reducing the likelihood of a fire and lowering its intensity if it does occur.

Species	Tonnes/ hectare	Annual fall
Mountain Ash (80m)	22	8
Messmate-Peppermint (30m)	19	
Red Stringybark (15m)	17	3
Grasslands	17	

Fuel accumulation rates in eucalypt forest.[116]

Most fires occur naturally in the hot summer months of January–February. It is not surprising that most plants and animals have completed their breeding between autumn and springtime, thereby avoiding fire at this critical stage in their life cycle. Many plants in fire prone environments, such as grasslands, will disappear underground over summer. It follows then that an unseasonal fire is likely to be more damaging to an ecosystem.

Snow Gum (*Eucalyptus pauciflora*) showing a fire scar (grey dead wood) surrounded by numerous attempts by the tree to regrow over the scar. Each of these attempts followed a fire event. We can interpret this as showing relatively frequent, low intensity fire. The frequency of fires varies across landscapes. © Lucas Bluff.

Fire mosaics and animals

WHAT HAPPENS to arboreal marsupials, like possums, when a fire passes through a forest? The answer depends on the fire severity – whether it is hot enough to kill trees, remove hollows etc. – how much unburnt habitat is left behind (refuges) and the extent of burnt forest in the surrounding landscape.

Firstly, a general rule is that there are more arboreal marsupials the more hollows that are present.

After fire, Sugar Gliders and Leadbeater's Possum are extremely rare on burnt sites no matter what was the fire severity. Even if their habitat remained unburnt, these two species decline if the surrounding landscape is burnt. This may be due to their need to range widely in search of their invertebrate prey.

Mountain Brush-tailed Possum and Greater Glider occur on burnt and unburnt sites. There are fewer Greater Gliders if the fire is severe and much of the landscape is burnt. Mountain Brush-tailed Possum is least common on sites burnt at moderate severity.[117] Loss of breeding hollows is likely to be important in the decline of these species.

Some animals show a distinct response to fire, others none (see the Mallee chapter for more examples).

In conclusion, fire is an episodic disturbance of great significance in shaping ecosystems in Victoria.

With young, thin-stemmed juveniles surrounding it, this old Snow Gum's position on a large rock appears to have helped it to escape a fire on Mt St Gwinear. © Meredith Platt.

Observing the prior fire regime

IMAGINE THAT you are standing in the bush. How could you have any idea what the fire history has been at your location? Some visible indicators are pictured here. Detailed mapping of fire history is also potentially available from government and university sources, as well as satellite imagery. There are many signs to look for.

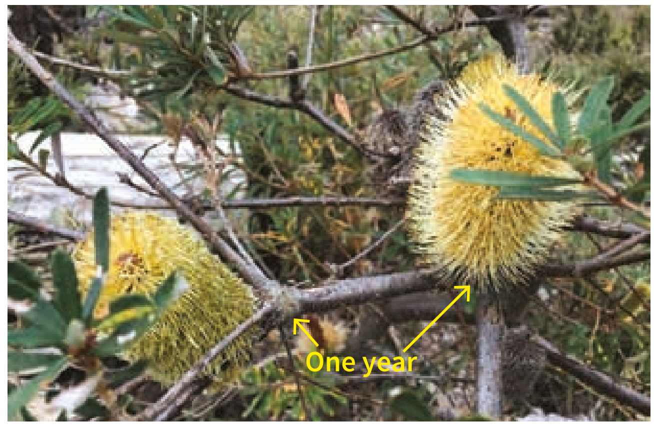
Short-term indicators

Fire induced flowering (e.g., as in some grass trees) **is an indicator of a very recent fire.** © Stephen Platt.

Charcoal on the soil surface or in the soil profile indicates previous fires; the closer to the surface, the more recent the fire. In this picture, the fire was less than 12 months prior. © Stephen Platt.

Bunches of shoots, called **coppice**, emerge from buds post fire. They remain for up to 5–10 years, eventually falling off as the tree returns to its canopied form. © Stephen Platt.

Absent skirts on grass trees indicates a recent fire as they are rapidly replaced over a few years. © Stephen Platt.



The internodes of *Banksia marginata*. Each section of growth between nodes represents a year since the seedling emerged post fire. Start counting at the base. © Stephen Platt.

Intermediate term indicators

The presence of fire-cued, understorey, obligate seeder species such as wattles and peas indicate a fire that stimulated their mass germination. If you are familiar with the species' lifespan then it is possible to guess the approximate fire date. These wattles at Heathcote may be around 5–10 years old. © Stephen Platt.

Plants that appear at known intervals post fire. Plants such as Kangaroo Apple (*Solanum laciniatum*) and White Elderberry (*Sambucus gaudichaudiana*) flourish in the first few years after fire in the tall wet forests near Marysville then diminish in abundance as the forest regrows. Long-term fire regimes can be deduced when knowledge of the plants that occur at different post fire periods of time is known. © Stephen Platt.

Kangaroo Apple. © Stephen Platt.

White Elderberry appears and fruits immediately post fire. © Stephen Platt.

The nearness to peak flowering (if known) is a rough guide to time-since-fire.[118] For example, Hairpin Banksia (*Banksia spinulosa*), an obligate seeder (does not resprout after fire), takes 13 years to reach maximum flower production.[119] © Stephen Platt.

Lifespan of post fire pioneers. This Silver Wattle (*Acacia dealbata*) is senescing (dying and full of beetle larvae – note the rust-coloured frass at the base of the trunk). This suggests that a fire occurred approximately 20–25 years before, which is the approximate lifespan of this species. © Stephen Platt.

Charring of bark. The amount of charring on stringybarks is a reliable indicator of time-since-fire at a site. As the bark expands with age and weather erodes the bark surface, so the amount of charring decreases. This site has been burnt within the last year as indicated by 100% cover of bark char (detailed method page 64). © Lucas Bluff.

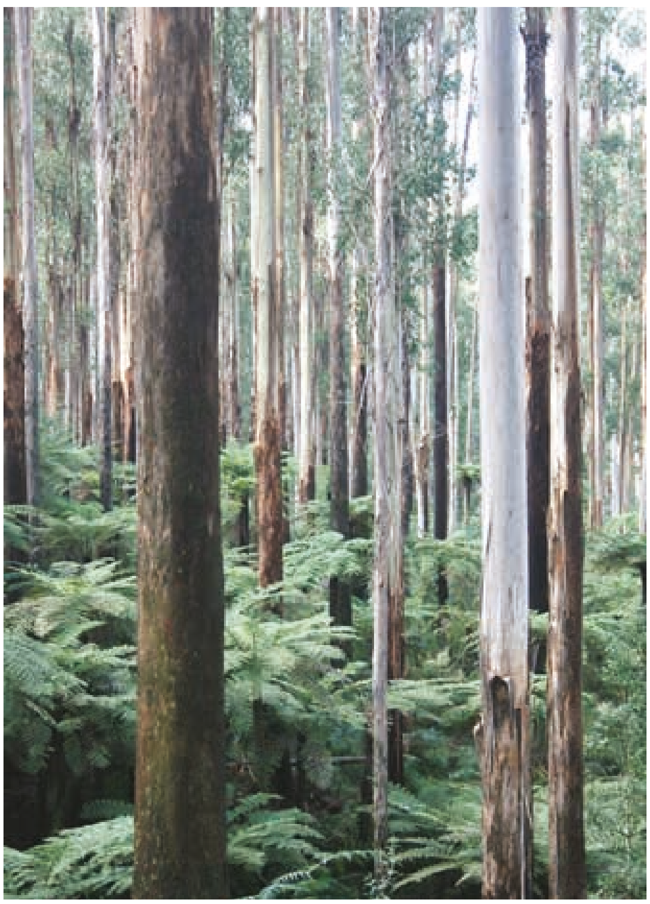
The invasion of vegetation by fire sensitive species such as Sweet Pittosporum (*Pittosporum undulatum*) or, along the coast, Drooping She-oak (*Allocasuarina verticillata*). © Stephen Platt.

The silvered tops of fire-killed trees. These can often be seen emerging above a forest canopy. The charring on the tree in the centre of this image most likely indicates that it was dead prior to the fire that killed its neighbours which are now silvered (and dead) after losing their bark. © Stephen Platt.

Long-term indicators

The fire history of a site over long (>50yr) timeframes may be indicated by **black bands in grass tree leaf bases**[120,121] **charcoal deposits in soil**, evidence of fire adapted species in pollen cores, and satellite imagery.

Fire scars at the base of trees (usually where phytofall accumulates on the upslope side of a tree). In this example, the living tissue of a Snow Gum has partially grown back over a fire scar in response to multiple fires. © Lucas Bluff.



In tall wet forests, **cohorts of trees of similar age** can provide a clue to a past severe fire that triggered mass germination of seedlings. The age of the trees tells us the time since the fire. In this case, Mountain Ash on the Black Spur (originally a travel route for aborigines and called the 'Black's Spur') were planted after the 1939 bushfires. © Stephen Platt.

The presence of long-lived, fire sensitive plants such as Mountain Plum Pine (*Podocarpus lawrencei*) indicates long-term absence of fire. © Stephen Platt.

Plant growth ring counts (dendrochronology) of species that emerged from seed following a fire. © Heidi Zimmer.

Recognising fire in the landscape – the junction between burnt (foreground) and unburnt, old growth Coastal Tea Tree (Wilson's Promontory N.P.) is indicated by a red line.
© Stephen Platt.

If you have more fire-patchiness, do you get more animal species?

IT IS an appealing idea – if different species like vegetation at different times since the last fire, why not create more fire patchiness and therefore support more species? Field studies on Patch Mosaic Burning or 'pyrodiversity' have found for and against this idea. Critics have pointed out that the mosaic needs to be meaningful ecologically – for the species, the landscape and the context (e.g., different during a drought to a wet period).[122,123,124] For example, many threatened mallee birds are dependent on long-unburnt vegetation and a patchier mosaic with less long-unburnt would not benefit them.[125] The answer also depends on the objective. What benefits one species may not benefit another. We need to be wary of simple solutions to complex problems in natural systems.

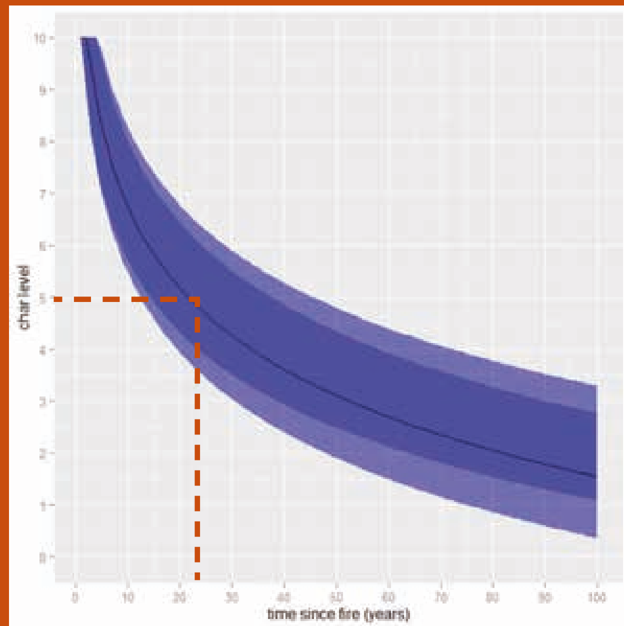
CHAPTER COVER: The large chunks of charcoal and phytofall-free soil surface are a clear indication of a recent fire, as is the extensive post-fire flowering. In the background, epicormic shoots cover a burnt gum tree. Steels Creek 2009.
© Stephen Platt.

Testimony to the adaptability of many species, in a radically altered landscape following the 2006 alpine fires at Mt Cobbler, this Flame Robin chose to nest in a cavity very close to the ground despite predators, such as copperhead snakes, having easy access. © Stephen Platt.

Bark char as a way of estimating time-since-the-last-fire

The charcoal left behind after fire on the stringy bark of gum trees has been found to be a reliable indicator of time-since-the-last-fire. To estimate the time-since-fire look at a sample, say ten, stringybarks at about breast height. Mentally estimate the average proportion of charcoal. A few specks of charcoal (5%) indicates a fire some 50–80 years ago, half (50%) charred about 10–20 years since fire and nearly all char (>90%) is very recent, within the last five years.[126]

In the example at right, the char level of 5 corresponds with an estimate of 24 years since the last fire.



Char retained on stringybarks can be used to estimate time-since-the-last-fire.

Why that bark?

BARK COVERS the outside of all gum trees and its extraordinary variety gives rise to common names like 'stringybark', 'ironbark', 'gum' and 'box' (from which the Melbourne suburb of Box Hill is derived[1]). But what determines the bark type on a gum tree?

For many animals, bark is a significant habitat in itself. Different bark types support different organisms.[127] Stringybarks and ironbarks have been found to support the largest numbers and most diverse communities of invertebrates.[128] Decorticating (peeling) bark provides under-bark spaces for many species (e.g., bats, spiders) to shelter, hunt and breed, whilst retained bark does not.

Ironbark in cross-section. © Stephen Platt.

Bark is the exterior covering on all woody (non-herbaceous) plants and is made of dead cells. It is not involved in photosynthesis (not green).

Some gum trees are covered in a thin layer of smooth bark referred to as 'gum' bark, others in a 5cm thick, ridged 'iron'-bark. Sometimes the thick, rough bark covers the trunk and branches, other times it occupies only the lower trunk with smooth bark higher up.

Generally, the larger the tree canopy, the thicker the bark.[129] Also in general, thick bark provides more insulation and thin less.[130]

Red Gum in cross-section. © Stephen Platt.

Why is there so much variation and what is the role of bark?

BARK IS likely to have evolved in response to multiple environmental factors. Like skin on a human body, bark has a fundamental protective role. It provides insulation, protection from pests, predators and disease, and protection against mechanical damage. Bark also protects the inner, sugar-transporting cells (secondary phloem). If the tree trunk is mainly there to hold the tree's branches and leaves aloft, and connect them to the water and nutrient-seeking roots, then the bark is there to make sure the trunk and branches remain in good condition to perform this role.

Factors that appear to influence bark type include:

- Competition and life strategy
- Fire
- Soil nutrient status
- Landscape position

These key factors interact and are influenced by climate and the plant's energy balance.

1 Long-leaved Box and Yellow Box are native to Box Hill.

The different bark types and their response to fire is clearly shown in this low intensity planned burn. Messmate Stringybark (*Eucalyptus obliqua*) is scorched to its upper branches whilst gum-barked Blue Gum (*Eucalyptus globulus*) has minimal scorch at the base. © Stephen Platt.

Arguably the greatest influence on eucalypt bark type is fire and saving the life of the tree given the near certainty of fire at some interval. After all, trees cannot run from the heat of a fire. The frequency of a thick bark skirt at the base of most eucalypts, even those mostly covered in gum bark, seems at first glance to support this idea.

It is tempting to think that variation in bark type is directly related to the likelihood and severity of fires in the landscape but it is not as simple as that.

A tree must withstand the intense heat of a fire without damage to the thin living layer just beneath the bark (cambium).

Not all bark types respond to fire in the same way. Thin, gum bark is usually fire resistant whilst stringy bark, when desiccated, burns readily.

Bark thickness and bark flammability are key factors in fire resistance[131,132] but so is bark density, moisture content and heat transfer.

So, what does the experimental data show? A comparison of heat penetration between three species – Messmate (stringybark), Narrow-leaf Peppermint (box bark) and Candlebark (gum bark) – with thick, medium and thin bark respectively, found that heat penetration was greatest in Messmate and least in Candlebark, or the opposite of what you might expect from their bark thickness.[133] This pattern was repeated in another study for Ironbark and Yellow Gum.[134] Curiously, Ironbark was the least effective at preventing the living cambium from reaching lethal temperatures of >60°C and Yellow Gum bark the most effective.

Let me try to explain what might be happening. Much of what follows is speculative. Consider what happens to a forest gum tree during a bushfire. Its roots are safely stored underground and do not need to be protected from fire. The canopy is afforded some protection through its height. Whilst leaves might burn, finer branches and gum nuts usually survive. The canopy's need for protective bark will therefore largely be influenced by the amount of radiant heat and flames arising from fine fuels in the ground and shrub layer. Where shrubs are dense and burn readily, high fire intensity and thick bark is expected. Where the understorey is sparse and fire intensity low, thinner bark is expected.

Now let's consider the interplay of competition between species, wetness, soil fertility and landscape position.

Let's assume:

- competition is greatest in wet, fertile locations
- wetness affects both the likelihood of fire and the amount of fuel
- soil fertility influences plant growth and the ability to invest in bark
- landscape position relates to all the above and the likely fire regime.

As explained earlier, in moist, fertile locations trees must grow tall to compete with their neighbours. Bark for fire protection comes at a cost, in terms of energy available for growth, that these trees can ill afford. Given that they live in wet places and that their height places their seeds well above the worst fire, bark is perhaps an unnecessary extravagance especially as the tree can allocate internal moisture to fire protection. This may explain why we often see gum-barked species in gullies and why some tall, obligate seed regenerators, like Mountain Ash, have gum bark. The observation that many eucalypts are clothed in rough bark at the base, where fire will be most intense, but grade into smooth gum bark higher up suggests that there must be an advantage to smooth bark even in habitats subject to fire.

In high altitude locations, trees are less likely to experience intense fire due to slow rates of fuel accumulation in the cold, wet and sometimes snow-covered mountains. Thick bark is just not needed. High mountain eucalypts also tend to be gum-barked (e.g., Snow Gum *Eucalyptus pauciflora*, Black Sallee *E. stellulata*, Brittle Gum *E. mannifera*).

At lower elevations where soils are relatively high in nutrients and there is a dense shrub layer to fuel a fire, trees can and must invest in fire protection via bark as fire is inevitable, relatively frequent and fairly intense. Here we find the peppermints and stringybarks. They are cloaked in a fibrous bark that lights up readily and draws the flames upward quickly, usually saving the trunk.

Soil nutrient status will also affect a plant's capacity to create fire defences, either bark or chemical. Tannin, a chemical found in bark and other parts of the tree, provides fire resistance.[135] Tannin is responsible for the brown, 'tea-stain' colouration common in Victorian streams. Tannins also have a role in controlling insect pests.[136] Black Wattle (*Acacia mearnsii*) is particularly known for its tannin content. So perhaps where water is limited but not nutrients, chemical defences play a greater role in fire protection. We would thus predict thinner bark in areas of seasonal water shortage but good soil fertility.

On the dry plains of Victoria, even though the soils are relatively fertile, there is less risk from fire due to a sparse understorey. We would expect less investment in bark. This may explain the relatively thin, fibrous bark of Grey Box *E. macrocarpa* and Yellow Box *E. melliodora* communities. Add periodic flooding and fire risk is even lower. Hence, for River Red Gum (*E. camaldulensis*) and Yellow Gum (*E. leucoxylon*) communities gum bark is adequate.

The thickly-barked, though fire sensitive, ironbarks are an anomaly being situated on nutrient poor soils with sparse understorey vegetation and where intense fire is rare. We would expect them to have thin bark so other factors are probably at play.

What about the value of bark in providing protection against pests, predators and disease? In this role bark needs to be continuous and entire (uncracked). Cracking is most likely in trees that undergo water stress. Water stress is most likely away from reliable water supplies in sites subject to drought. Hence, trees might avoid cracking by living close to water or, for those living in dry places, perhaps by having 'pre-cracked' fibrous bark, as do the peppermints and stringybarks.

But what about gum trees that deliberately shed their bark such as Mountain Ash (*E. regnans*) and Manna Gum (*E. viminalis*)? If it costs energy to create bark, why drop it off? The trees that can most afford to lose bark are those that have lots of water and nutrients to fuel photosynthesis. Shedding bark allows them to grow rapidly in girth as they grow skywards in competition for light. It is an inevitable consequence of growth. These eucalypts tend to be gum-barked and so lose a relatively small amount of bark through bark loss (decortication). Whilst the bark they drop can contribute to a fire, it rarely does as these trees grow in wet places with dense understorey vegetation that dries out infrequently. Shedding bark might also be a defence against climbing plants.

Further studies are needed to clarify the role of bark.

1. Snow Gum, 2. River Red Gum, 3. Grey Box, 4. Yellow Box, 5. Red Stringybark, 6. Red Ironbark. © Stephen Platt.

Frederick McCoy (1817–1899)

SIR FREDERICK McCoy has been described as being, at the time of his death in 1899, "Australia's most distinguished scientist" as well as "that bad tempered, red headed Irishman" and an 'impractical academic'. As the foundation Director of the Museum of Victoria, first Chair of Natural Science at the University of Melbourne and first President of the Field Naturalists Club of Victoria, he was also an anti-Darwinian and unenlightened voice both for and against the importation of exotic animals to Australia. Hard working, obsessive for detail, intolerant of others and a poor teacher, McCoy was meticulous and passionate about advancing his legacy. He was responsible for establishing Victoria's Museum and its natural history collection of half a million specimens by the time of his death. His expertise in fossils allowed him to conclude, for the first time, that the rock sequences of the southern hemisphere were the same as those in other parts of the world. We all take the geological timescale as a given now. His success came at much personal financial cost as, when government funds were insufficient, he frequently purchased museum items out of his own pocket. McCoy suffered personal tragedy when his wife, son and daughter all died within five years of each other. McCoy was an intelligent, complex and driven individual who played a foundational role in understanding the natural history of Victoria.[137]

Telling of the success of the breeding of English birds at the Botanic Gardens, McCoy said that thrushes, blackbirds, larks, starlings, and canaries had all been liberated and were now living in the grounds, and breeding freely without care from the attendants or any food being given them.

Professor McCoy in his anniversary address (on 24th November 1862) said that eight starlings had been released at the Botanic Gardens, together with 18 canaries, 2 Californian quail, 18 blackbirds, 2 partridges, 24 thrushes, 6 skylarks.

When McCoy had finished his address—and his listing of the birds and mammals which would happily fill what he thought was the silent and lifeless interior—T. T. A'Beckett, M.L.C., rose

McCoy foolishly backed the work of the Acclimatisation Society that would go on to have devastating consequences for nature across Australia. At that time, ecological concepts were only beginning to take shape (extracts from 'They all ran wild').[138]

McCoy's Skink *(Anepischetosia maccoyi)* was named in honour of Frederick McCoy.

Mallee – the great sand pit

In this scene in Victoria's Mallee, sharply-spined, individual spinifex grass plants are growing. Between them is open sand with scattered lichens and mosses. Multi-stemmed eucalypts, but almost no phytofall, are visible. Some dead trees and branches are in the background. What is going on here? Why does it look like this?

Mallee – the great sand pit

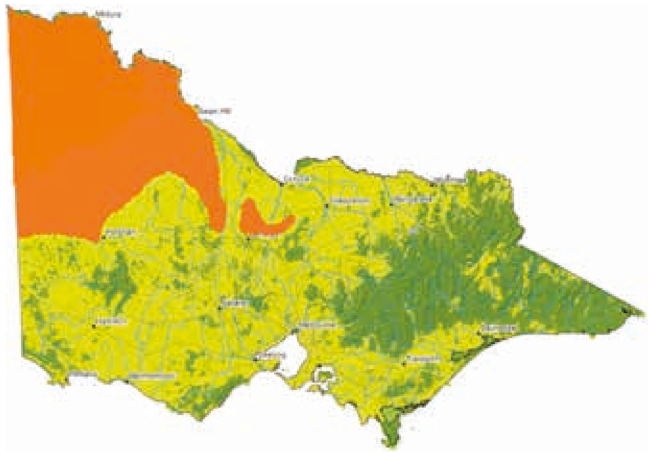
***A VANISHING** ocean, an underground woody 'magic-pudding', a prickly grass house, eye licking, a killer crocodile roll, buried alive but still kicking, a snake mimic, a procession to food – the ingredients of life in the great sand pit that is the Victorian Mallee.*

Introduction

THE SHIMMERING inland heat, the burning hot sand followed by freezing nights, the unrelenting dryness, limited shade, pincushion-shaped and spiny clumps of Spinifex grass (*Triodia scariosa*), all-consuming fires; north-west Victoria is a reptilian paradise!

In the bushland of far north-west Victoria a number of eucalyptus species have developed the same multi-stemmed form and are collectively called 'mallee' (see page 11 for why they are this shape). The region also takes its name from this plant formation, being called the Mallee.

The word 'mallee' was first used by European settlers in 1848 to describe vegetation formations dominated by multi-stemmed species of *Eucalyptus* and is derived from an Aboriginal word.[139]



Approximate distribution of mallee vegetation in Victoria.

Typical multi-stemmed, mallee eucalypt. © Stephen Platt.

Ecosystem outline

MALLEE VEGETATION is instantly recognisable due to the multi-stemmed, short eucalypts that dominate the vegetation. They grow in sandy, alkaline soils often overlaying limestone rocks and on rolling sand dunes in an otherwise largely flat, semi-arid landscape.

The mallee habit is under partial genetic control[140] and is a response to environmental stress. In this case the stress comes from aridity and fire.

The distribution of mallee vegetation is sharply delimited by winter rainfall of between 200–500mm. Rainfall is low but more reliable than in the arid zone further inland.

Mallee has been described as the transition vegetation between the dry interior of Australia and the savannah woodlands to the south. This crossover region contains elements of both.[141]

Mallee vegetation forms a belt across southern Australia ending in north-west Victoria. The mallee habit in eucalypts possibly evolved in Western Australia.[142]

Mallee soils are predominantly made of sand. Millions of years ago the sand had been washed down the Lachlan, Murrumbidgee and Murray Rivers which, due to a much wetter climate, were a lot bigger and carried large volumes of sand-laden water from the highlands. Vast quantities were involved and a layer 40–150m thick and covering approximately $40,000 km^2$ was created.[143] An unrivalled sand pit!

The approximate distribution of predominantly mallee vegetation in Australia. After Hill.[144]

The sand found its way into Australia's Murray Basin – of which the Victorian Mallee is part. The Basin is a huge depression draining into South Australia's Coorong. Over long timeframes, due to changing sea levels, the Basin has been invaded by the sea numerous times.

Picture yourself on the coast of this ancient sea with a shoreline running ~500km from the Grampians to the Mt Lofty Ranges and parallel to the Coorong. Waves crash on the shoreline and the tides come and go. Stand there for a *very* long time and imagine the sea gradually retreating toward the horizon, stabilizing for a time and leaving behind a sand ridge and another beyond that, and another. Stand there for a few million years (between 6.6 and 3.5 million years ago[145]) and the entire landscape before you has become a plain of hundreds (~600)[146] of north-north-west-oriented stranded coastal ridges. Some are 50m high, several kilometres wide and several hundred kilometres long.[147] The sea's retreat is the result of a cooling climate that has locked water up as ice at the Earth's poles. The Mallee sits in the place of an ocean that vanished.

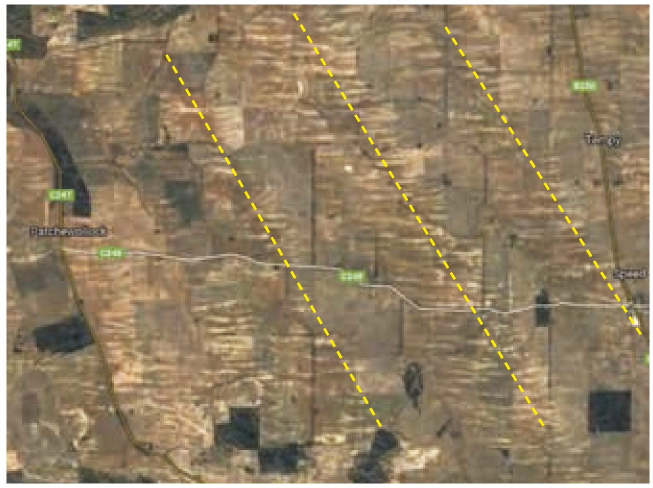
The most extreme marine incursion was about 25 million years ago. At that time the sea reached to near the junction of the Murrumbidgee and Lachlan Rivers and almost to Horsham. This shallow sea of lagoons left behind 130m thick alkaline, limestone deposits and a lot of salt.

In addition to the coastal ridges (which are difficult to recognise on the ground) are sand dunes formed by powerful winds ('of Aeolian origin'). Some dunes run parallel with the predominant wind direction of east-west, whilst others are crescent-shaped. Each dune type has differing parent soils and origins.[148] The dunes are the dominant features on the ground. Within them is a sprinkling of an 'exotic' soil component, probably from Antarctica.

In between each dune is a flat trough, called a 'swale', and many small, shallow, salt lakes and gypsum flats, the sea-derived salt having been brought to the surface by the sun and evaporation.[149]

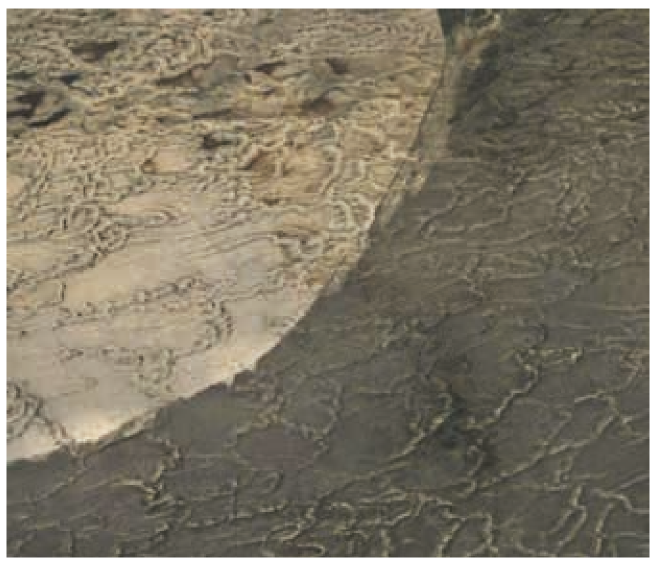
Mallee soils were also influenced by uplifting. About three million years ago a block of land was pushed up, blocking the Murray River and forming a huge lake, called Lake Bungannia. The fine sediments deposited in the lake formed clay soils. Eventually the lake breached its barrier and the lake drained.

Around 300,000 years ago, the Mallee's climate changed to be more arid and cycled between dry and wet until the most recent dry period beginning 32,000 years ago. This was the dune-building period and resulted in the current dune-covered landscape.



Coastal ridges between Patchewolloch and Tempy, Victoria. Source: Google Maps.

Parallel dunes in Murray-Sunset N.P. Source: Google Maps.



Wind-blown, crescent-shaped 'Jumbled Dunes' in the Big Desert. The area at top left has been burnt. Source: Google Maps.

Dunes in Red Bluff Nature Conservation Reserve.
Source: Google Maps.

***Dunaliella salina*, Lake Tyrrell.** © Mike Dyall-Smith CC BY-SA 4.0

Salt-tolerant plants, such as Round-leaf Pigface (*Disphyma crassifolium*), occupy the floor of a shallow, ephemeral wetland named Rocket Lake in Murray-Sunset N.P.
© Stephen Platt.

Spinifex and other drought tolerant, small-leaved plants occupy the dunes. An abandoned Emu nest is in the foreground. © Stephen Platt.

Pink Lakes, Murray-Sunset National Park. The pink colour is due to a single-celled algae (*Dunaliella salina)* that thrives in the salty lake. © Stephen Platt.

Cottony Saltbush (*Chenopodium curvispicatum*) is a fleshy-leaved plant found in Chenopod Mallee. The flowers may be male, female or bisexual. © Stephen Platt.

Thus, we see the Victorian Mallee today – a dry, sandy, infertile, alkaline and salty expanse of country carrying its own unique plant and animal life. There are very infertile rolling sand dunes interspersed with flat, salty swales. On more fertile (more organic matter), moister soils, mallee eucalypts may give way to *Allocasuarina* groves. In places, the water table reaches the surface as salt lakes with hues of blue, green and pink due to the salt-loving algae that live in their salty water.

On the dunes grows vegetation that can cope with deep, dry, shifting sand. Sand yields its water more readily than clay but that doesn't help when the water can drain away to below root depth. The hummock-forming, drought tolerant, spiny grass 'spinifex' grows here in abundance giving rise to the name Hummock-grass Mallee for the dune vegetation. In the swales between the dunes, where the soil contains more fine clay and more salt, grows Chenopod Mallee. Chenopods (saltbushes) are salt-tolerant plants, particularly *Atriplex* and *Chenopodium* species, often with fleshy leaves. Heath mallee grows where soils are poor in nutrients and Mallee-Broombush (*Eucalyptus incrassata-Melaleuca uncinata)* on slightly more fertile soils.

In this hot, dry environment, with regular summer electrical storms as a source of ignition, fire is to be expected. Fires tend to be *all consuming* as fuels are dry enough most summers to burn and *large*, as there are few topographic or moisture barriers to halt fire spread.[150]

Chenopod and Hummock-grass Mallee vegetation are capable of carrying a fire 10–20 years after the previous fire; much sooner (within two years) if a high rainfall event has stimulated widespread growth of short-lived (ephemeral) grasses (particularly of spear grass *Austrostipa* spp.).[151] As you watch the rain fall in the Mallee, be aware of the increased likelihood of fire in the following years.

The maximum time between fires in Hummock-grass Mallee is around 90 years and in Chenopod Mallee 200 years. The difference in these intervals is because Chenopod Mallee has much less fire-prone vegetation. Heathy Mallee vegetation can burn again in less than 10 years after a previous bushfire.

Mallee-Broombush (*Eucalyptus incrassata-Melaleuca uncinata* association) grows quickly after fire taking advantage of its nutrient-rich soils then, after eight years, its growth rate declines as its structure becomes irregular. This increases evaporation in summer and less soil moisture leads to slower growth. On the other hand, Heathy Mallee recovers more slowly at first on its nutrient-poor soil but then increases its growth rate with age. Its uniform structure retains moisture and with time key species have time to explore the whole soil nutrient profile and maximise their growth rate.[152]

Chenopod Mallee. © Stephen Platt.

Fuel accumulates very slowly in the dry environment of the Mallee. Fires, when they occur, are all-consuming of above-ground vegetation. © Mallee HawkEye Project, LaTrobe University & DELWP. CC 3.0 (Aust.).

Mallee vegetation before (top) and after (bottom) a planned fire from precisely the same vantage point. Whilst ground and shrub layer vegetation has all been consumed, tree structure remains relatively intact, though killed by the intense fire. © Natasha Schedvin, Mallee HawEye Project, LaTrobe University & DELWP. CC 3.0 (Aust.).

In spite of its readiness to burn, due to chance and the protection offered by previous fires, patches of mallee vegetation can remain unburnt for more than a century.[153]

An assessment of Mallee fires that occurred over a 35-year period, found that 40% of the area (104,000 km^2) had burnt but that less than 3% had burnt more than once. A few large fires accounted for most of the area burnt and this is probably the typical pattern.[154] It can take decades to centuries for the vegetation to recover its pre-fire characteristics.

Mallee gum with a large lignotuber. © Stephen Platt.

Shoots emerge from the lignotuber immediately post-fire. © Stephen Platt.

Ring of stems arising from regrowth after a fire. © Stephen Platt.

The stem size of mallee gums can be used to predict the time that has passed since the last fire.[155] A stem diameter of 5cm on Dumosa Mallee (*Eucalyptus dumosa*) may indicate 35 years have passed since it was last burnt. © Stephen Platt.

Mallee gums have a special structure that sits just below the soil surface, the 'mallee root' (a lignotuber), that helps recovery after fire. It may weigh over 600 kg and contain in excess of 13,000 buds[156] some of which will re-sprout after fire. A number of these buds will grow to replace the original trunk, all the while supported by the existing root system that remains alive. If the tree has lived through several fires, the root system may be much older than the above-ground stems (potentially a thousand or more years although to date radio-carbon dating has only confirmed 200 years). Resprouting is a low-risk strategy in this unpredictable environment where conditions for seedling establishment may be decades apart. Lignotubers can resprout numerous times so even repeat fires are survivable. This 'magic pudding' gives mallee gums a critical advantage over many other species. As the new shoots grow, a 'ring' of new stems develops. Hence, the multi-stemmed form of mallee gums.

As the root system remains alive after fire, the original plant can retain its grip on water resources, thus preventing competitors from establishing.

Different plant species occupy a site at different times after fire. Thus, if you were walking through an area that last burnt ten years ago you would be more likely to encounter Sugarwood (*Myoporum platycarpum*) and Tar Bush (*Eremophila glabra*). After 30 years Dark Turpentine (*Beyeria opaca*) and Nealie Acacia (*Acacia loderi*) would be more common and a long time after fire Ruby Saltbush (*Enchylaena tomentosa*) and Common Twinleaf (*Zygophyllum apiculatum*) would indicate you were standing in a special place that had escaped fire for many decades.[157]

Most animal species' responses to fire are tied to their shelter, feeding and breeding requirements and these vary depending on how recently an area was burnt.[158]

The abundance of most reptiles in this environment is influenced by time-since-fire.[159] Nocturnal, burrowing reptiles tend to be present soon after fire whilst reptile phytofall specialists arrive as the vegetation matures.[160]

Burrowing amphibians avoid fire by sheltering underground. Their abundance is closely linked to soil moisture.

Some animal species *irrupt* immediately after a fire, such as the Chestnut-rumped Thornbill (*Acanthiza uropygialis*) and introduced House Mouse (*Mus musculus*), taking advantage of resources freed up by the fire event.

Others, such as Painted Dragon (*Ctenophorus pictus*) and Coral Snake (*Brachyurophis australis*), *decline* as the recently burnt vegetation ages. If you want to find them, look in vegetation burnt less than ten years ago.

Ruby Saltbush indicates that an area has not been burnt for many years. © Stephen Platt.

Marble-faced Delma (*Delma australis*). © Matt Clancy. CC BY 2.0 Generic.

Able to use its partially prehensile tail to assist in climbing through spinifex in search of invertebrates, the Southern Ningaui lives for just 14 months. © Tim Bawden. CC BY.

Another group of species, including Marble-faced Delma (*Delma australis*) and Southern Ningaui (*Ningaui yvonneae*), are most abundant in the middle years between the typical minimum and maximum fire interval, or around 40 years post fire.

The Yellow-plumed Honeyeater (*Lichenostomus ornatus*) is less likely to be found in young vegetation but peaks in the mid years and remains steady after that – a *plateau* response.

Lastly, there is a group of species where the likelihood of finding them increases steadily as the vegetation ages. This group includes Gilbert's Whistler (*Pachycephala inornata*) and Southern Scrub-robin *(Drymodes brunneopygia*).

The animals present are simply responding to the food, shelter and breeding resources that are present at different times after fire. At 15–50 years post fire the maximum abundance of Spinifex advantages another group of species. After 100 years, hollow formation and the sparse understorey suit another suite of species (see page 77).

Rainfall also affects the response of animals. If wet years follow a fire, then animals tend to occur earlier and more abundantly in the post fire vegetation.

Also important is the effect of grazing and browsing animals. Mature Spinifex is very unpalatable but many other species are palatable. They are strongly influenced by herbivorous animals such as kangaroos.

Long unburnt mallee is particularly important in providing hollows used by many species of wildlife.

Hollows are a critical resource for animals as they provide a place to escape dehydration by the sun, to avoid predators and breed safely.

Both the time since a fire occurred and the time between successive fires has been found to affect whether hollows are present. The longer the time since fire, the more chance there are hollows.

In living Mallee trees, hollows start to develop after 40 years. Hollows in dead branches peak at 50–60 years. Longer intervals between fires increases the number of dead branches that contain hollows.[161]

The swales are less fire prone due to their flat topography and sparse, fleshy-leaved (semi-succulent), ground-layer plants. Mallee gums tend to grow to a greater age in these fire-protected areas and so their branches contain larger hollows used by larger wildlife species such as the Sand Goanna and Owlet Nightjar.

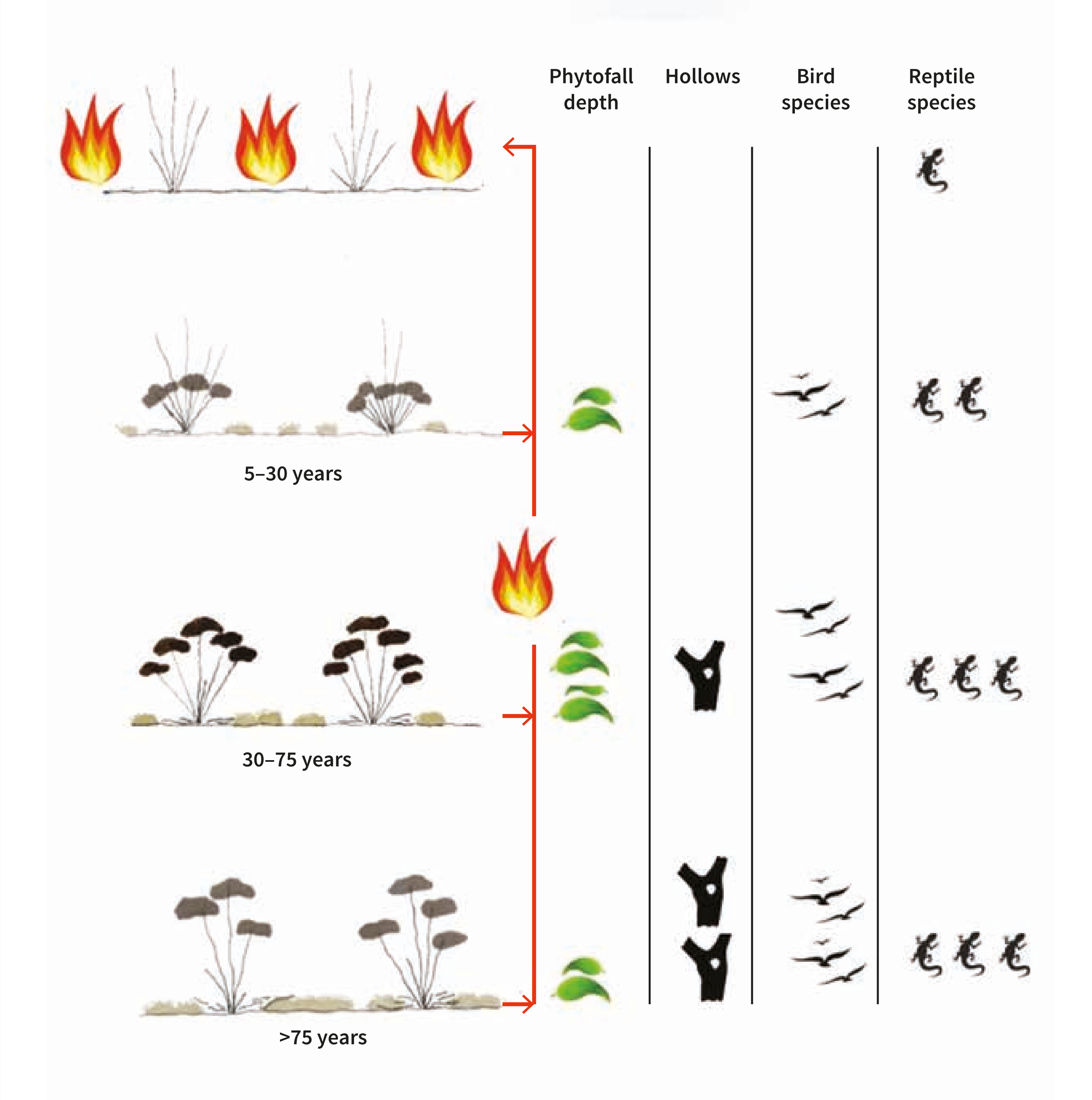
Thus fire, through its interaction with the resources animals need to survive, is integral to what species are present and where they occur in the Mallee.

Yellow-plumed Honeyeater nests are parasitised by several species of cuckoo. © Juliet Lowther.

Gilbert's Whistler prefers a habitat of Spinifex and low shrubs including wattles, hakeas, sennas and hop-bushes.
© Juliet Lowther.

Owlet Nightjar in a hollow of a mallee eucalypt.
© Natasha Schedvin & Louise Durkin, DELWP. CC 3.0 (Aust.).

Visualizing changes in Mallee post fire



This diagram indicates how abundance of birds and reptiles changes with time-since-fire following the development or decline of critical resources – phytofall and hollows. Source: Avitabile, S. (2014). Mallee HawkEye Project: Final Report. La Trobe University, Melbourne.

Wander around the mallee and you will very rarely see recruitment of mallee gum trees. Despite there being around eight million seeds per hectare held in the canopy of Yellow Mallee (*Eucalyptus incrassata)*, and two million seeds dropped per year, few viable seeds occur in the soil. So why? Seed-harvesting ants are one of the main culprits. They gather and consume 65–100% of the tiny seeds.[162]

Ants are perfectly designed for spreading out across a surface to find small objects of food, such as eucalypt seeds. Half the seeds fallen are gone within just five days and most within a couple of weeks. So how does Yellow Mallee produce new generations? After a fire, huge quantities of seed held in woody gumnuts in the tree canopy are dropped onto the soil surface (300/m^2) swamping the ant's ability to remove them quickly.

Large numbers of seeds are incorporated into the soil, through animal activity and wind, where they remain viable for up to 300 days. Seed dormancy may be broken by heat and soil changes following a fire (the fire may suppress soil microbes) in combination with cooler winter temperatures and rainfall. In the occasional years of sufficient rainfall, they will germinate and start to grow.

High rates of seedling death are common. Usually, these young trees would be outcompeted for water by existing mature trees and die. They must also fight against their siblings. In one study, three quarters of seedlings died within two years.[163] However, after a fire some of the adult mallee gums will have died (5% died within two years of a fire compared with half a percent in unburnt areas[164]) thus releasing water resources for any new seedlings.[165] With water and space to grow, a new generation can appear. Due to their long lifespans, only a few seedlings need to survive to replace the existing adults. Hence fire can be a life-giver as well as a life-taker. Even with fire, seedling recruitment in the dry mallee environment is rare and widely spaced in time, coinciding with rainfall events. So, mallee vegetation usually appears to the casual observer as unchanging, mature and childless. Look a bit harder and you will see the effects of fire, ants, and water.

Ants are a dominant feature of these dry environments.[166] They live in colonies that begin with a winged male and female selecting a new site for a colony. She becomes a queen and may live for 30 years. He dies within a few weeks leaving his sperm with her. She lays rice-grainsized eggs. Eggs hatch into grubs (larvae) which pupate before emerging as mature ants. Unfertilised eggs turn into male workers and fertilised eggs female workers. The workers live just one to three years.

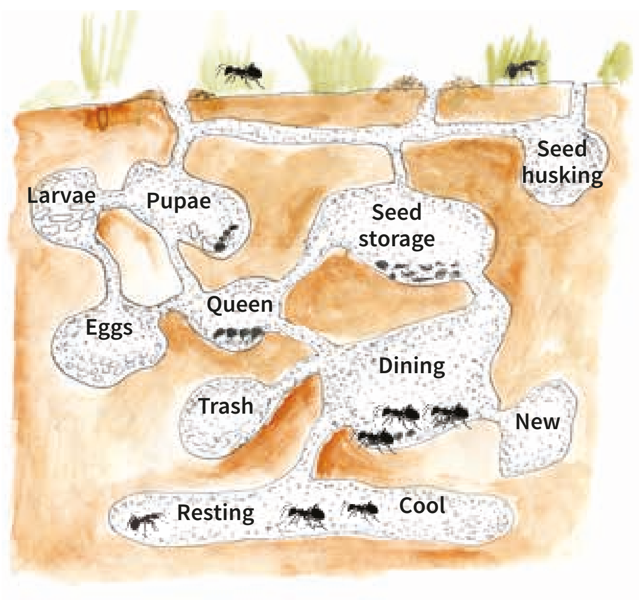
Species of ants can be active by day, or by night, or switch between day and night – so don't assume a nest is inactive just because no ants are seen in daylight hours. Ants forage on all surfaces including the soil surface and in a tree canopy.

The uncommon sight of mallee seedlings. © Stephen Platt.

The caterpillar of the Mildura Ogyris Butterfly (*Ogyris subterrestris*) spends its life underground probably eating the larvae of the Sugar Ant *Camponotus terebrans*.
© Mark Newton CC-BY.[167]

Mildura Ogyris Butterfly. © Indrabone. CC-BY-NC 4.0 (Int).

One study in north-west Victoria recorded 86 species of ant in a small area just 50m x 25m. Ant activity was highest in summer and lowest in winter. Most activity in summer was during the night whilst in winter ants were out during the day. Over time, different species were more, or less, abundant giving rise to different communities of ants. Ants are primarily influenced by temperature but probably also by competition among similar species, largely avoided because they are separated in time (day/night, seasonally, post fire).[168] Fire had a substantial impact on the ant community, increasing the diversity of species, probably due to reduced competition from the dominant species, whilst reducing the overall number of individuals.[169],[170]



Generalised diagram of an ant colony. © Stephen Platt.

Plant life

THE DIVERSITY of plant species in the Mallee is high – around 100 species per hectare – with some specializing in the open areas between trees and others under the canopy.[171]

Around one quarter of mallee plant species are endemic to the Mallee.[172]

The position of the Mallee in the crossover zone between the dry interior and wetter coast is behind this diversity. Plants from both environments are represented in Mallee vegetation.

Most plants show features to conserve water such as small leaves and umbrella shapes, which provide sunshade and help to direct morning dew and rainfall toward the root zone.

Typical water-harvesting, umbrella shape of a shrub in the Mallee. © Stephen Platt.

Spinifex occupies the dunes. It burns easily but it can rapidly regrow from shoots protected by resins in the centre of the tussock or from seed.

Spinifex provides critical habitat for animals. It's silica-tipped, finely-pointed, outward-pointing leaf blades are a deterrent to most predators. Inside the Spinifex hummock, where conditions in the shade favour invertebrates, is a source of food for reptiles and small mammals. Running between Spinifex hummocks, reptiles risk predation by birds. Snakes are not deterred by Spinifex leaves and seek prey within. Spinifex reaches its maximum ground cover 30 years after a fire. Species like the threatened Mallee Emu-wren (*Stipiturus mallee*) and Mallee Ningaui (*Ningaui yvonneae*) prefer a high cover of Spinifex and so are found most abundantly in vegetation that is 15–30 years post fire. Mallee Emu-wren reach highest densities where there is at least 15% ground cover of Spinifex.[173]

It is possible to get an idea of the time-since-the-last-fire by looking at the size and shape of Spinifex clumps. Spinifex that is in a single clump is relatively recently burnt whereas Spinifex that forms a large donut-shaped ring is relatively long unburnt.

Small leaves help to conserve water in dry environments as shown by comparing the leaves of Narrow-leaved Red Mallee *(Eucalyptus foecunda*) [at left] and a wet forest specialist, Blue Gum (*Eucalyptus globulus*). © Stephen Platt.

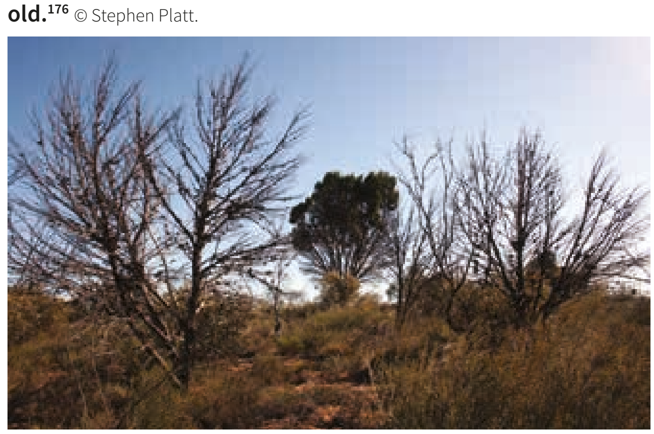
A ball of sharp spines. Spinifex offers refuge to many small animals. © Stephen Platt.

Large Spinifex 'rings' only form in the absence of fire. The ring-form of Triodia does not occur until about 30 years post fire.[174] © Stephen Platt.

Scrub Cypress-pine (*Callitris verrucosa*) is a conifer that can grow to 5–10m in height. It is a fire sensitive species although large, old individuals with bark thickness of 1–1.5cm may have some resilience to fire. It is palatable to species such as rabbits, which eat its seedlings.

If the vegetation remains unburnt for over 100 years, Camphor Wood will start to dominate the dunes where it occurs.[175]

Trunk diameter is a good indicator of a Scrub Cypress-pine tree's age. Thirty-centimetre diameter trunks indicate plants up to 170 years old, five-centimetre trunks are about 25 years old.[176] © Stephen Platt.



A Scrub Cypress-pine survivor lives on the dune crest, a fire refuge, whilst others lower down the slope have died in a fire. © Stephen Platt.

Dune slopes are more fire prone due to the presence of the fine fuels of Spinifex grass and the tendency of fire to burn quickly up slope. However, dune crests can act as fire refuges as a result of the sparse vegetation that can grow in this driest of locations. Camphor Wood survives on dune crests due to its superior ability to withstand drought. It produces very little leaf or branch debris (phytofall) to fuel a fire. Ants associated with Camphor Wood may assist in clearing surface fuels near the plant. In the absence of fire, Camphor Wood can invade the dune slopes only to be forced back onto the crest when a fire occurs.

Ant nests are often associated with particular plants such as this Camphor Wood. © Stephen Platt.

Section through the stem of a Scrub Cypress-pine. © Heidi Zimmer.

Animal life

MALLEE ANIMALS can withstand heat and lack of surface water. Some are capable of sudden irruptions following good rainfall with dramatic changes in numbers. The fauna includes sand 'swimmers' (e.g., the Two-legged Spotted Burrowing Skink *Lerista punctatovittata*) and limbless species (e.g., Burton's Snake Lizard *Lialis burtonis*). Large predators patrol the air, such as Wedge-tailed Eagle, and land, including large goannas, but most species are small and unseen.

There are many reptile lifestyles including burrowers and tree climbers, large predators and prey, egg layers and live-bearing species. The proportion of species active by day or by night is similar.[177]

Some bird species, such as the Regent Parrot, feed in the Mallee but shelter and breed in the adjacent River Red Gum Forest along the Murray River. Whilst burrowing frogs are represented, other aquatic species are a small component due to the lack of waterbodies.

Animals show a range of adaptations to the arid environment. Mammals and reptiles use burrows and soil cracks to avoid climate extremes. Many are nocturnal, thereby avoiding the midday heat, and concentrate their urine to reduce water loss. Breeding throughout the year, storing fat in the tail and periodic deep sleep (torpor) are also employed by some species.[178]

A significant number of medium-sized mammals, including soil excavators (several bandicoots), predators (Western Quoll, Red-tailed Phascogale) and grazers (several wallabies and bettongs) have become extinct here and the Mallee is forever altered due to their absence.

The Mallee is the domain of reptiles which like the heat and can cope with the dryness (Australia has more reptile species than any other country[179], followed by Mexico and Brazil). This diversity has been explained in terms of the infertile soils on which Spinifex grows leading to few herbivores but lots of termites which are particularly suited for reptiles to feed on, often at night. This abundant food resource has allowed reptiles to diversify. In addition, unreliable rainfall and consequently plant growth has favoured reptiles over birds and mammals.[180] Lastly, the pattern of sparse tree growth in arid areas provides abundant resources for termites and thus reptiles. Pick up any fallen dead branch that has been in contact with mallee soil and its light weight will indicate the highly-effective foraging activities of termites.

Visit the Mallee in winter and you are unlikely to see many reptiles. All reptiles must obtain their body heat from external sources. This usually requires basking in the sun. In winter, most reptiles would have to bask for a long time whilst exposed to predators. Instead, they find a safe refuge and live off the fat stores they produced over the active spring and summer months.

Spinifex is a very important habitat, especially for reptiles. It provides protection from predators and food in the form of invertebrates. Reptile densities are highest where there is extensive cover of vigorously growing Spinifex.

For cold-blooded animals (animals that are unable to regulate their own body temperature), heat assists not only with daily activity but also the incubation of eggs. But too much heat can kill. Thus, a reptile unable to find shade may die in the sun from overheating.

The Hooded Scaly-foot (*Pygopus nigriceps*) is a lizard that resembles a snake. Its long, slender body has no trace of forelimbs and just a scaly flap of a hind limb. You might imagine this is an adaptation for swimming through sand but the scaly-foot lives on the surface and is mainly active by night. In this case, loss of limbs probably provides an advantage when slithering through Spinifex clumps or sheltering in cracks, insect holes or under rocks. They lay two parchment-shelled eggs and, lacking an eyelid, have the ability to lick clean their clear-spectacled eyeball with their unforked tongue.

Their food includes insects, spider egg sacks and scorpions – delicious! Larger prey is quickly despatched with a crocodile roll. If under threat, the scaly-foot, with markings that resemble those of a young brown snake, mimics the tongue-flicking and raised head stance of its highly venomous double. If grabbed it squeaks and may drop its tail to distract a predator.

Stumpy-tailed Lizards (*Tiliqua rugosa*), also called Shingle-back Lizards, are a kind of blue-tongued lizard. When alarmed they open their jaw widely and stick out their dark-blue tongue, which contrasts with the lighter mouth, to scare potential predators such as birds-of-prey. A bite from their strong jaw can bruise the skin but it is not true that the bite reappears for many years hence. Though living alone for most of the year, at mating time they form long-term, pair bonds. One to four live young are born in late summer to autumn. Upon emerging, they eat the placenta that aided their development and must immediately be able to care for themselves. Stumpy-tails are omnivorous, mainly eating plant material. Why the fat tail? These fat reserves are important as a resource when breeding and in surviving drought. Stumpys live for over 35 years.

The Sand Goanna (*Varanus gouldii*) is a voracious predator, active by day. It constructs a large burrow for shelter and egg-laying (termite mounds are also used). Food consists of a wide variety of organisms and carrion.

Hooded Scaly-foot. © D H Fischer. CC-BY-NC 4.0 (Int).

Lacking eyelids, reptiles can lick their eyeballs clean. The unforked tongue identifies this as a legless lizard and not a snake. Common Scaly-foot (*Pygopus lepidopodus*).
© Nick Clemann.

Millewa Skinks (*Hemiergis millewae*) are confined to mallee habitats and only occur in long-unburnt Spinifex, probably because it provides shade from the sun and a deep leaf layer containing insect prey. They give birth to one or two live young in summer (viviparous). © Peter Robertson.

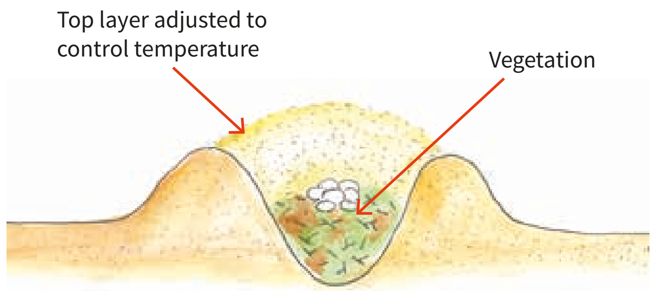
Stumpy-tailed Lizards rely on food reserves stored in their tail for breeding and to survive drought. These large lizards were eaten by Aboriginal people. © Lorraine Phelan. CC-BY-NC-SA 4.0 (Int).

Sand Goanna. © Mallee HawkEye Project/LaTrobe University & DELWP. CC 3.0 (Aust.).

Malleefowl. © Donald Hobem. CC 2.0 Generic.

A male, turkey-sized Malleefowl (*Leipoa ocellata*) is a very attentive parent. He will excavate a hollow in the sand, between mallee gums, some three metres wide and a metre deep. Into this he will pile vegetation and sand scraped from the surrounding area until it forms a prominent mound in the shape of a mini volcano that he will defend for three-quarters of the year. He regularly excavates and mixes the mound contents to encourage plant material to decay and so produce heat.

Malleefowl mound. © Stephen Platt.



Malleefowl mound in cross-section. © Stephen Platt.

At the end of winter, he excavates a chamber in the top of the mound and his life-long female partner lays around 15 eggs into it. He then reforms the mound covering the eggs. The buried eggs, like that of many reptiles and extinct dinosaurs, but unlike most other birds, have evolved to *not* have an air-sac inside.[181] The male continues his vigilance removing or adding vegetation and sand to maintain the perfect temperature in the mound for chick development. After up to 100 days the chicks hatch and, lying on their back and digging with their legs, make their way to the surface. They emerge, take their first breath, stand like a statue for up to twenty minutes, then scurry off into the bush where their ability to freeze and blend into their surroundings will help them to escape predators. They will never see their parents or siblings again. What a way to start life!

Major Mitchell's Cockatoo (*Lophochroa leadbeateri*) is one of numerous large, long-lived parrots found in the Victorian Mallee. They are a conspicuous presence and often raucous. Major Mitchells require trees with large hollows for breeding. They have a preference for Slender Cypress Pine trees (*Callitris gracilis*) over 170 years old. Such trees are of great age and thus rare. In the chosen hollow, usually near a watercourse, she lays several eggs on the wood shavings at the base of a deep vertical hollow shaft. Chicks fledge at around four months of age, reach sexual maturity at three to four years and live for up to 83 years. They are omnivorous and feed on seeds on the ground or in shrub and tree canopies where they gouge insect larvae out of branches. In areas with insufficient water they may be sedentary or nomadic. Unlike many of its relatives that have benefitted from agriculture, this species requires intact woodlands of conifers, she-oaks and eucalypts which have been cleared for agriculture leading to its decline.

The endangered Mallee Emu-wren (*Stipiturus mallee*} is found in Spinifex Mallee. It generally keeps close to the ground and is a poor flier. Small groups search for invertebrates, particularly beetles and seeds. Their domed nest is made of grass, bark and Spinifex leaves and placed in a clump of Spinifex. Recent studies have found that, at higher elevations (55–98m) Mallee Emu Wrens declined in abundance about 50 years since fire, while at lower elevations (28–55m) they showed no decline. The cover of Spinifex showed a similar pattern which suggests that it is the decline of Spinifex at higher elevations that leads to declining Emu Wren abundance post fire.[182]

Splendid Fairy-wrens (*Malurus splenden*s) occupy small ~4.4ha territories year-round. They live in small groups that forage on the open ground and in shrubs for small invertebrates. At the slightest hint of danger, they will quickly retreat to a dense shrub. During courtship the male will pluck and display pink or purple petals. Socially monogamous but sexually promiscuous they are none-the-less attentive parents and the group co-operates to feed the young born in the territory. Their nests are often parasitised by Horsfield's Bronze or Shining Bronze Cuckoos.

Major Mitchell's Cockatoo. © Graham Winterflood. CC-BY-SA 4.0 (Int).

Male Mallee Emu-wren. © Nik Borrow. CC Commercial.

Splendid Fairy-wren, Murray-Sunset N.P. © Stephen Platt.

You wouldn't expect frogs to live in this formidably hot and dry environment but they do, though there aren't many species. The Mallee Spadefoot Toad (*Neobatrachus pictus)* is a powerful burrower. It spends much of its life underground in the humid soil, safe from the Mallee heat and bushfires. When rainfall fills ponds and lakes, it emerges to breed. The eggs and tadpoles are reliant on freestanding water and rapidly develop into adult frogs. As the landscape dries the frogs, having eaten for a short time, rebury themselves to wait until the next wet. Aboriginal people had the knowledge to locate and extricate desert frogs, a source of water in critically dry times.

The Bag-shelter Moth (*Ochrogaster lunifer*) lives for just a few days. The female lays up to 500 eggs on a food plant, usually a wattle, and covers them in scales from her body for protection. After hatching, the caterpillars feed on the leaves of the host plant at night. During the day they shelter in a silken bag. It progressively becomes messy with cast off skins and faeces. If the host plant is fully stripped, the caterpillars head off in a procession, one after another, looking for another. Hence, they are also known as processionary caterpillars.

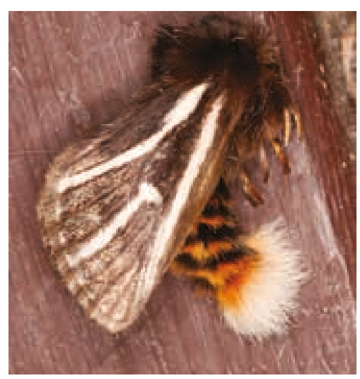
Cylinders of soil, visible in winter and spring, extruded from the earth in a pile give this animal its common name of 'Sand Turd Beetle' or 'Earth Borer Beetle' (*Blackburnium sloanei*).

The beetles push up columns of damp sand like toothpaste from a tube. They burrow in search of fungi which they feed on. The large facial shield probably helps with burrowing through the sand and the horn may play a role in tussles between rival males for access to females.[183] They are also suspected of spreading mycorrhizal fungi that are important in plant health. Their vertical tunnels can reach 2m in depth. Earth borer beetles rarely come to the surface and then mostly at dusk. Their biology is poorly known. Some species lay just one large egg. They are thought to be long-lived.

Southern Spadefoot Toad. © Matt Clancy. CC 2.0 Generic.

Looking like a pile of dung, this mound was actually made by an Earth Borer Beetle. © Stephen Platt.

Earth Borer Beetle, probably *Blackburnium sloanei.*
© Fiona Murdoch, CC-BY-NC 4.0 (Int).



Processionary caterpillars of the Bag-shelter Moth marching off to find a new host plant.
© Kenneth Foster. CC BY 4.0. Bag-shelter Moth Victor Fazio. CC-BY-NC 4.0 (Int).

Halgania Moth (*Utetheisa pulchelloides*). © Stephen Platt.

In conclusion, the heat, the rainfall pattern and low availability of standing water, the sandy soils with limited nutrients, fire and seed harvesting by ants are all influential in creating Mallee ecosystems. The need for animals to escape predators, to find food and to breed and raise young, are accomplished via different strategies using the resources unique to the Mallee including sharp-spined Spinifex and sandy soils.

Human survival in the mallee

THE MALLEE, like much of central Australia, is a harsh place for humans to live. However, indigenous people had mastered the knowledge to survive here.

Spinifex had numerous uses by Aboriginal Australians. The resin was collected for use as an adhesive in spear-making, clumps were burnt for signalling and seeds were collected to make cakes.

Sections of mallee tree roots, which spread out radially near the soil surface, were dug up to obtain water.

> *"The eucalypts of the mallee species thrive in deserts and droughts, but contain water in their roots which only the native inhabitants of the country can discover…A very long root such as I have mentioned might give nearly a bucketful of water; but woe to the white man who fancies he can get water out of the mallee…it is an Aboriginal art at any time or place to find it."* **Ernest Giles**

> *Having cut the root into six-feet lengths and tied them in a bundle, he looped his belt around the bundle and hung it vertically from a tree, the lower ends being placed in the water bucket…Half an hour later we had our first drink and though the water to me seemed slightly woody, it was quite good…Tuck had found these trees often of great value to him. 'Many's the time they've been all I've had—an' don't I know it', he added grimly.* **Archer Russell**[184]

This skill permitted travel in areas without freestanding water.[185]

Chapter cover: Interpreting this image we can see isolated clumps of spinifex (no doughnut-shaped clumps) which indicate that this area has been burnt fairly recently. However, the Spinifex clumps in the foreground appear to be in a circle and may have originated from the same plant. The fist-sized diameter of the eucalypt stems indicates a stem-consuming fire some 35–40 years ago. The presence of spinifex and lack of fleshy-leaved shrubs indicate we are looking at the summit of a dune. This is excellent reptile habitat and tracks left in the sand might show activity such as snakes chasing small lizards as prey. The age and density of spinifex (~15% cover) shown here is approaching that required for Mallee Emu-wren to be present.

Where to see this ecosystem

- Murray-Sunset National Park
- Hattah-Kulkyne National Park
- Annuello Flora and Fauna Reserve
- Big Desert Wilderness Park
- Little Desert National Park

Historical note

In 1969, a proposal to clear the Little Desert for agriculture led to a public campaign to save it for conservation. As a result, the Land Conservation Council was formed to advise government, free of political interference, on appropriate public land use.[186, 187]

Getting to know our reptiles and amphibians

1. Barking Gecko © Ray Turnbull CC-BY-NC 4.0 (Int), **2. Woodland Blind Snake.** © Dr Damian Michael. CC-BY 3.0 (Au), **3. Coral Snake.** © D. H. Fischer. CC-BY-NC 4.0 (Int), **4. Painted Dragon**. © Reiner Richter. CC-BY, **5. Spotted Marsh Frog.** © Reiner Richter CC-BY 4.0 (Int), **6. Tiger Snake.** © Stephen Platt.

Getting to know our reptiles and amphibians

Herps	Taxa	Threatened	%
Reptiles (native, incl. five marine	153	40	26
Amphibians (native)	51	15	29
Reptile/amphibians (introduced)	0	0	0
Total (native herps)	204	55	27

Reptiles

REPTILES LACK the cellular mechanism to maintain a constant internal body temperature (are ectothermic, previously referred to as 'cold blooded') but different species reach and maintain desirable body temperatures behaviourally by basking in sunshine, seeking cover when it is too hot, vibrating body muscles or obtaining heat from rotting vegetation or warm surfaces like rocks. When temperatures get too cold, they can remain inactive and reduce their energy consumption. Having low energy requirements and skin that minimises water loss enables reptiles to survive in environments where food and water supply is unreliable and erratic, such as the deserts.

Lifespans range from one year (Mallee Dragon *Ctenophorus fordi*) to decades (Stumpy-tailed Lizard, 35+ years).

Types

The main groups are turtles, lizards and snakes. Lizards are represented by geckos, legless lizards, skinks, dragons and goannas. Snakes include sea snakes, blind snakes, pythons and venomous snakes.

Habitats

Reptiles occupy all environments and habitats in Victoria from the coast to the alps (e.g., White-lipped Snake *Drysdalia coronoides*) and Mallee. Diversity and abundance increase as we move to the north west of the State following a gradient of increasing temperature and reduced, unreliable rainfall. The ground layer, including rocks, crevices and phytofall, is particularly important to reptiles as places of refuge, for foraging and breeding.[188] Some species are also good climbers and utilise tree hollows.

Reptiles are highly vulnerable to fire. An estimate of wildlife killed during the 2020 bushfires suggested that 143 million mammals perished, 180 million birds, 51 million frogs and 2.46 <u>billion</u> reptiles. This large number reflects both reptile density, particularly of skinks, and their limited means of fleeing fire.[189]

As a sign of submission, the Tree Dragon or 'Jacky Lizard' (*Amphibolurus muricatus*) raises its front foot and moves it in a waving action. © Stephen Platt

Mallee Dragon © Steven Dew CC-BY.

White-lipped Snake feeding on a skink. This snake is very cold tolerant and lives in high alpine areas.
© Reiner Richter. CC at the record level.

Southern Rainbow Skink. © Daniel Pendavingh. CC-BY

Communication

Lizards and snakes communicate through movement, including tail raising, arm waving (e.g., Jacky Lizard *Amphibolurus muricatus*), opening jaws, raising a crest (e.g., Painted Dragon *Ctenophorus pictus*), head bobbing and sticking out their dewlap (skin under the chin, e.g., Gippsland Water Dragon), via changes in colour (e.g., changing to breeding colours – Eastern Three-lined Skink (*Acritoscincus duperreyi),* Southern Rainbow Skink *(Carlia tetradactyla*), through smell and the use of chemical signals and pheromones, sound (e.g., Barking Gecko *Underwoodisaurus millii*), hissing (various snakes and lizards) and vibration. The Pink-nosed Worm Lizard *(Aprasia inaurita)* emits high-pitched squeaks when alarmed.

Feeding

Reptiles eat a great variety of foods with diet depending on the species. Many skinks prey on a variety of invertebrates.

Coral Snakes (*Brachyurophis australis)* feed exclusively on reptile eggs. Lowland Copperhead Snakes (*Austrelaps superbus)* and Tiger Snakes (*Notechis scutatus)* mainly eat frogs, but will also eat other snakes. Diamond Pythons (*Morelia spilota)* seek out possums and bandicoots. Woodland Blind Snakes (*Anilios proximus)* have been found with ant larvae in their stomach and Eastern Beaked Gecko (*Rhynchoedura ormsbyi)* preys almost entirely on termites. Burton's Snake Lizard (*Lialis burtonis)* feeds primarily on small skinks. Large goannas are capable of eating animals as large as possums, eggs and nestling birds. The larger skinks, such as Blue-tongued Lizards (Blotched and Western), are omnivorous and consume fruits and fungi in their diet.

Movement

Most reptiles undertake daily movements to thermoregulate. There are seasonal variations whereby some species are active in summer and dormant in winter. Most occupy limited home ranges. Tiger Snakes have a home range of up to 12ha but mainly use a core area of just 2ha. Tree Goannas (*Varanus varius*) occupy a home range of 107–387ha.

This Lowland Copperhead Snake is hunting in the intertidal zone on French Island. © Juliet Lowther.

Eastern Beaked Gecko © kdm801 Attribution 4.0 International (CC BY 4.0)

Courtship and Breeding

A wide range of behaviours are used in courtship and breeding. Some species change shape and colour.

Ritual male fighting (which is something like two humans hand wrestling), as males assert their dominance, over a female occurs in snakes and monitors until one male is overpowered. These combative displays can be seen in spring (and autumn for some venomous snakes). Male turtles display their vigour by ramming rivals with their head and body. Some populations of Bynoe's Gecko reproduce without mating (parthenogenesis) but Victorian populations reproduce sexually.

The egg 'shell', a crucial reptile feature (reptiles were the first group to evolve an egg shell), prevents egg desiccation on land (a reason why frogs are confined to wet places). Most reptiles lay soft-shelled eggs in a burrow. However, gecko eggs are hard-shelled. Some species give birth to live young (e.g., Blue-tongued Lizard). In these cases, food for the developing embryo may come from the egg yolk or via a placental connection.

Some species, particularly skinks, lay in communal burrows containing the eggs of their own or other skink species. Communal egg laying is widespread among animals (481 spp.). The underlying reasons remain unclear.[190]

Male lizards and snakes have paired mating (copulatory) organs; turtles and tortoises have one. Mating usually occurs in spring although some species in cold environments mate in autumn.

This female Blue-tongued Lizard died as a result of her injuries but the vet was able to rescue her 12 live young. © Carla Foreman.

X-ray of a Stumpy-tailed Lizard showing live young inside. © Carla Foreman.

A Grey Shrike-thrush (*Colluricincla harmonica*) rapidly consumes this skink, not being fooled by the writhing tail it has discarded. © Stephen Platt.

Tiger Snake (*Notechis scutatus*) © mbdbirds CC-BY-NC-ND 4.0 (Int)

Ecological role

Reptiles are a significant part of ecosystem food webs. They are prey to many other species and also predators.

Amphibians

AMPHIBIANS (MEANING 'double life') evolved from bony fish some 345 million years ago. They were the first vertebrates to live on land.

Types

There are three families of frogs in Victoria. The 'southern frogs' include two families. The third family of 'tree frogs' are distinguished from the southern frogs by having pads on their fingers and toes. Three species of turtle inhabit Victorian waterways (see pages 35–36).

Habitats

Frogs occur in a wide variety of environments. There are fast flowing stream specialists (e.g., Spotted Tree Frog *Litoria spenceri*) and still water species (e.g., Pobblebonk Frog *Limnodynastes dumerilii dumerilii*). Some species survive on land by encasing themselves underground (e.g., Mallee Spadefoot Toad *Neobatrachus pictus*, Giant Burrowing Frog *Heleioporus australiacus*). Others live in cold alpine environments (e.g., Alpine Tree Frog *Litoria verreauxii alpina*, Baw Baw Frog *Philoria frosti*).

Shelter

Aquatic vegetation, streamside cobbles, burrows and hollows in trees provide shelter during daylight hours. Whilst breeding for most species typically takes place in the immediate vicinity of a body of water, the rest of the year may be spent several hundred metres from it (e.g., Giant Burrowing Frogs use up to 14 burrows up to 150m from their breeding sites along a stream). Some species (such as the Southern Toadlet *Pseudophryne semimarmorata*) are 'terrestrial breeders'; males build a nest and call-in females. Once the eggs have been laid and fertilised, the male guards the eggs. After hatching, rains wash the tadpoles into nearby bodies of water.[191]

To deter predators, most frogs have poison glands just behind the head. They obtain the poison from their food sources.

Common Froglet (*Crinia signifera*). © David Paul, Museums Victoria. Public domain. CC0.

Peron's Tree Frogs sheltering in a tree hollow near the Ovens River. © Stephen Platt.

Eastern Banjo Frog undergoing metamorphosis from tadpole to frog. © Matthew Connors CC.

Feeding

Tadpoles filter feed and browse on algae and detritus. An exception is the Baw Baw Frog. Its tadpoles live entirely off the egg yolk. Tadpoles' lifespan is anything from two weeks to a year before undergoing a remarkable change involving growing limbs and developing lungs. Young frogs are called 'metamorphlings'. Adulthood for most frogs is achieved in one to two years.

Communication, courtship and breeding

Adult male frogs call to advertise for mates and warn off competitors. With eggs that lack a shell, and an aquatic larval (tadpole) phase, most frogs are tied to water for breeding. Females lay a mass of eggs that the male fertilises. Fertilization occurs outside the body. A large number of eggs are laid (<100 to several thousand). The emerging tadpoles breathe through gills and are thus confined to water.

Some species, such as Marsh Frogs, encase their eggs in floating froth. Other species' eggs sink.

A frog's lifespan is around three to six years in the wild but some species live up to 16 years in captivity.

Ecological role

Amphibians are important parts of food webs. Frogs and tadpoles are food to a wide range of animals. They are predators of invertebrates, including many species of concern to humans such as mosquito larvae.

Blue Mountains Tree Frog (*Litoria citopa*)

A Green and Golden Bell Frog (*Litoria aurea*). Listed as vulnerable to extinction in Victoria.

Grasslands – fire and volcanoes

You may never see a scene like this in your lifetime as this is our most endangered ecosystem. Perennial tussock grasses are interspersed with herbs that have perennial and annual life strategies. What do you notice when comparing this vegetation type to others? © Stephen Platt.

Grasslands – fire and volcanoes

VAST PLAINS largely devoid of trees, hundreds of volcanoes, clay soils that become so sticky they pile up under your shoes, few endemic species but diverse, a spear that throws itself, native carrots and potatoes, from most prolific to extinct, a cuckold, breeding like a rabbit, natural fires every few years – the basalt plains are vast, different and culturally very significant.

Introduction

IT WAS day nine of the fateful Burke and Wills Expedition in 1860 when Ludwig Becker, the expedition botanist, sketched the explorers crossing the Northern Plains grasslands at Terrick Terrick. His diary records:

> *"The effect on one who sees extensive plaines for the first time is somewhat very peculiar: the plain looks like a calm ocean with green water; the horizon appears to be much higher than the point the spectator stands on, the whole plain looks concave. On you go, miles and miles, a single tree, a belt of timber appeared at the horizon, affected by the mirage; you reach that belt of small trees, a Wallaby, a Kangarooh-rat disturbs for a moment the monotony, and a few steps further on you are again on the green calm ocean."*

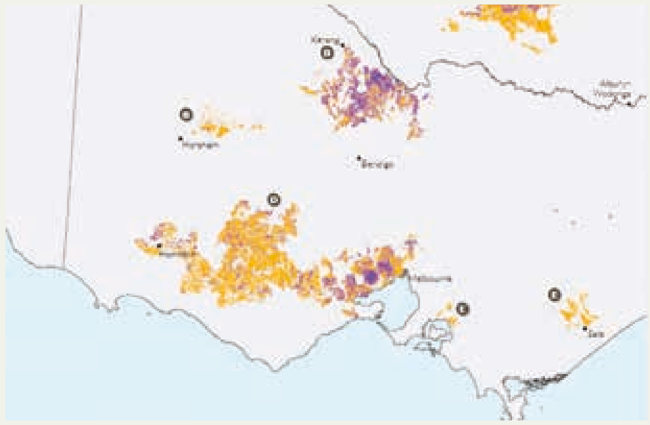
Open treeless plains supporting grasslands once covered large areas of Victoria, particularly in the south-west. They bordered Melbourne to the west and north west.

Ludwig Becker was not the first botanist to cast eyes upon the native grasslands of Victoria.

Native grasslands were perhaps the most important habitat for Aboriginal Victorians (with a density of 2.5–3.5 persons/km^2). Around 20 percent of the 550 plant species present were used as food and half of these had underground storage organs (tubers/carrot-like roots).[192] The botanists among a group of Aboriginal people must have truly been revered. They held knowledge of what could and couldn't be eaten, where and when to find it.

Ecosystem outline

NATIVE GRASSLAND ecosystems, those where trees and shrubs are largely absent, occur in Victoria in the Murray Valley (Northern Plains), between Melbourne and Portland (Volcanic Plains) and in Gippsland.[193] This discussion is largely about the Victorian Volcanic Plains in south-west Victoria. Unfortunately, only small fragments of the original Victorian Volcanic Plain grassland ecosystem remain.



Original distribution of native grasslands in Victoria.
© CSIRO Publishing.[194]

The Burke and Wills Expedition crossing the northern plains of Victoria near Terrick Terrick. Aug. 29. 1860 Ludwig Becker.
Source: State Library of Victoria.

Cast your eyes on the images immediately below. What is your reaction?

A nice flower? Potentially a weed? Both of these are native plants that form underground tubers ('carrots'). The one at left was a staple food of Aboriginal people. Millions of these plants grew across the grasslands and recognizing them during winter when the flowers have gone and the tubers are at their maximum, would have been a considerable skill. Left: Native Yam, Right: Blue Grass-lily. © State of Victoria (Department of Education and Training).

As far as the eye could see…native grasslands covered around 25,000ha of south-west Victoria. © Stephen Platt.

Scattered trees and shrubs such as Drooping She-oak (Allocasuarina verticillata), Silver Banksia (*Banksia marginata*), Sweet Bursaria (*Bursaria spinosa*) and the long-lived Lightwood (*Acacia implexa*), dotted the grasslands of western Victoria prior to the 1850's.

Painting by Duncan Elphinstone Cooper from Challicum (just east of the Grampians), Western Victoria. Source: National Library of Australia.195

Black-shouldered Kites (*Elanus axillaris*) seek prey by hovering over grasslands, a technique that works in a landscape with few trees. They primarily eat mouse-sized mammals. © Andrew Rock. CC-BY-NC 4.0 (Int).

The odd-looking, perennial Blue Devil (*Eryngium ovinum*) is a member of the carrot family (Apiaceae) and has a large taproot. It is very palatable to kangaroos and other herbivores. Flowers Nov.–Jan., dies down in autumn.

© Stephen Platt.

Blue Pincushion (*Brunonia australis*) at Rokewood.

© Stephen Platt.

Hot in summer, windy, almost shade-less, grasslands feel exposed and unfriendly to humans. Except along watercourses, around wetlands and on rocky knolls, they generally lack trees and shrubs for animals to climb on or perch, and branch hollows for shelter and breeding. The sky, patrolled by predators including kites and hawks, looms large above. Sunlight reaching the soil evaporates surface moisture and any water that collects in small depressions rapidly disappears in summer. It is largely a flat landscape of low to moderate rainfall.

In spite of these difficulties, plants and animals, including humans, thrived in native grasslands.

Why do plants look green?

Plants absorb blue and red light for photosynthesis and growth and reflect green light. This green light is what reaches our eye. Hence, we don't find many naturally-occurring blue plants.[196]

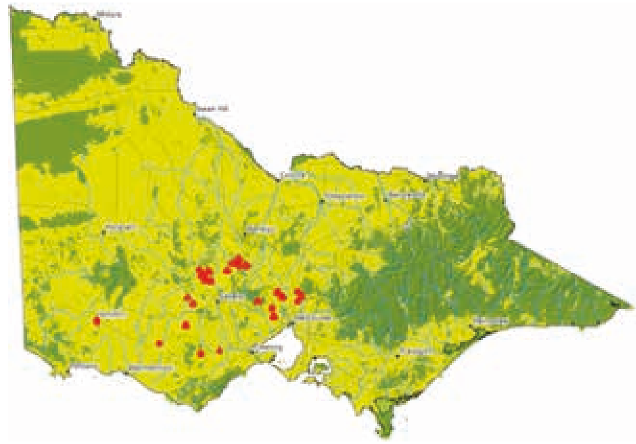
Native grasslands are diverse in plants. Over 100 plants, of 27 different species, have been found in a square metre.[197] In spite of this diversity, there are relatively few endemic species (species only found in these grasslands) probably because this is a relatively young landscape, formed by recent volcanic activity, that has been colonised from surrounding areas.

Why are there large areas with no trees? How do animals survive here without them? To understand these questions, we need to go back in time to the formation of the soils and the influence of changes in climate.

Much of Victoria's Gondwanan landscape was covered in dense rainforest vegetation. Fossilised pollen from around 11 million years ago suggests that this was followed by open forests and woodlands of eucalypts and she-oaks with grasses and daisies. As Australia separated from Gondwana and drifted northward, the climate died, fires became more common and the vegetation more open. Species that could adapt to fire thrived. Over the last 2.5 million years temperatures fluctuated between very cold and dry to warm and wet. During the dry, cold periods, extensive grasslands (steppe) covered the landscape. It was so cold and dry that trees were confined to sheltered locations such as river valleys. Subsequent warming has expanded tree cover but areas of treeless grasslands remain to the present day.

Across the vast Victorian Volcanic Plain (area about 25,000 km^2), clay soils derived from basalt rock cover most of the surface. Basalt is the solidified rock derived from molten lava. The tranquil landscapes of south-western Victoria today are in stark contrast to the preceding four to five million years when volcanoes belched gases, and lava flowed from vents, to form vast, relatively level, plains. There are over 400 'extinct' volcanoes in Victoria.[198] The most recent eruptions, at Mt Gambier in South Australia, were just 5,000 years ago. Most eruptions were relatively small and lasted for a short time producing shallow lava flows of 2–10m in depth. Where lava flowed down existing valleys, it can be over 60m deep.[199]

Underlying the relatively thin layer of lava are marine sediments from when, at a time of higher sea level, the edge of the sea reached to near the Western Uplands (the point where hills rise above the relatively flat plain of the coast). In some places these soils remain exposed.



Approximate locations of some significant volcanoes in south-western Victoria. There were more than 704 eruption points on the Victorian Volcanic Plains.[200]

Soil profile below a depression at Laverton North Native Grassland Reserve showing a white Kaolin clay layer beneath a much darker surface layer. © Stephen Platt.

Basalt columns nearly reach the surface at this site along the Geelong Road. Soils are red and very shallow. © Stephen Platt.

The oldest lava flows (5 million years) have weathered to develop deep soils (>10m) with white clay (kaolin) and iron nodules below the dark surface soils. The nodules formed in a hot, wet climate; much wetter than today's climate. Water dissolved the iron and carried it down through the soil profile where it collected as nodules. The white kaolin clays consist of crystals of alumina and silica. The precise method of their formation is unknown. Also known as 'china clay', kaolin is the raw material for porcelain pottery.

Lava flows of intermediate age (on to three million years) have one to two-meter-deep soils of red and black cracking clays. They are associated with narrow valleys and many lakes and swamps. Where the lava flow cut off drainage lines, lakes and wetlands have formed at the margins. These flows have eroded to have relatively flat surfaces.

The most recent flows (one million – 5,000 years ago) have a surface relief of 10m or more, with little or no soil cover. Weathering is in its early stages and features such as the jumbled rocks of 'stony rises' are evident. They can be seen near Pomborneit East, Mt Eccles and Mt Rouse[201], whilst the old volcanic cones can be seen in profile across the plains, including just north of Melbourne.

The absence of trees sets grasslands apart from most other vegetation types. In this grassland ecosystem, height, and with it the need to transport water vertically, is a big disadvantage as water availability is unreliable. In drought years, during summer, water is so limiting that trees and shrubs find it difficult to survive. Hence most grassland plants are short in stature above ground but may have long, deep, water-searching, rope-like root systems, or tubers, underground.

The combination of low to moderate rainfall, low winter temperatures and summer droughts appear to be the main regulators of the grassland – woodland boundary. Severe dryness, particularly in extreme years, is likely to kill any tree seedlings that have established in moderate years. Fire and grazing may have assisted in removing trees and shrubs, but they are probably not the main reason these open grasslands occur.

The lack of endemic species in Victoria's grasslands is probably due to the relatively recent timing of lava flows. Grassland species invaded from adjoining woodlands but have not had sufficient time to evolve into distinctive forms.

Stony Rises at the Pirron Yallock Creek at Millnmer's Station by Eugene von Guerard (1857). © National Gallery of Victoria, Melbourne.

Mt Elephant, a 380m high scoria cone of an inactive volcano near Derrinallum that last erupted around 180,000 years ago.[202] © Don Fuchs, Australian Geographic Image Collection.

Eugene von Guérard's drawing of Mount Elephant (c. 1858) shows an open plain with trees along a watercourse in the distance and a brolga in the foreground.
© National Gallery of Victoria, Melbourne.

A typical grassland species, Showy Podolepis (*Podolepis jaceoides*), in a grassy woodland west of the Grampians.
© Stephen Platt.

Consider taking an imaginary stroll around the Laverton North Native Grassland Reserve, 14km south west of Melbourne. The initial perception is of a paddock of grass, primarily Kangaroo Grass (*Themeda triandra*), which in early summer stands out for its rust-coloured stems. Spear (*Austrostipa* spp.) and wallaby grasses (*Rytidosperma* spp.) are also present in some areas. In elevated areas, there are emergent rocks and a close look among them will reveal a range of flowering herbs.

A small distance away the land begins a gentle downward slope, herbs increase in occurrence and are the main feature. The soils here are red and acidic.

Continue on and you will discover slight depressions that form short-lived (ephemeral) wetlands in the wet months. They have a different flora again and the soil they grow on is grey-black, deeply cracking and alkaline.

Lastly, you might discover a large, deeper but still ephemeral depression. On the edge are patches of grey clays that sick to the soles of your shoes. Here plants are sorted according to the depth of water they can withstand. The impression of many who first visit the grasslands, of a uniform field of grass, is an illusion. Minor variations in topography hint at the changing soil conditions and help explain the great variety and pattern of plants that grow here (see schematic interpretation page 100).

The seasons alter the nature of grasslands. In the heat of summer, clay soils develop deep, root-shearing cracks. Their clay particles hold tightly on to any soil water. In winter, the cracks fill with water until they expel it onto the surface, forming pools.

Grassland plants and animals are well adapted to fire. Fires probably occurred relatively often, approximately every three to seven years.[203] They consume all the above-ground vegetation but underground rootstocks remain untouched.

Kangaroo Grass. © Stephen Platt.

Herbfield. © Stephen Platt.

A shallow ephemeral wetland. © Stephen Platt.

Cracking clay soils support Common Nardoo (*Marsilea drummondii*), a fern that has been implicated in the death of the explorers Burke and Wills.[204] © Stephen Platt.

No perennial native grassland species rely on seed alone to survive a fire.[205] The tussock grasses resprout from buds located at the soil surface. Many species resprout from their bulbs which, over summer, lie safely beneath the insulating soil. So the grassland remains much the same as before the fire except for the increased light and water penetration as the sometimes-dense, leaf layer has been removed.

Recruitment of many plant species is cued to the combination of fire, that opens up space, and subsequent rainfall.

Low intensity, frequent, all-consuming fire is characteristic of grassland ecosystems. © Stephen Platt.

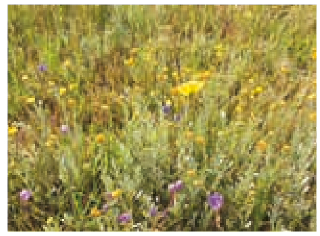
Masses of tubers form beneath Blue Grass Lily (*Caesia calliantha*) and support its rapid springtime growth. © Stephen Platt.

Inter-tussock spaces free of grass leaves, an indication of regular fire, aid recruitment of grassland plants. © Stephen Platt.

Schematic diagram showing the influence of microtopography on plant distribution at Laverton

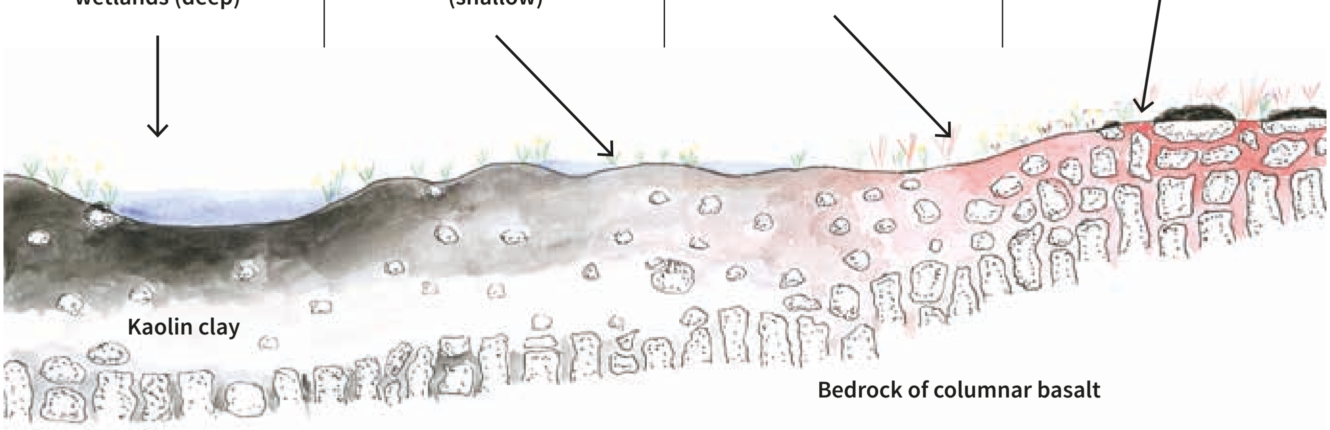
Semi-permanent wetlands (deep)

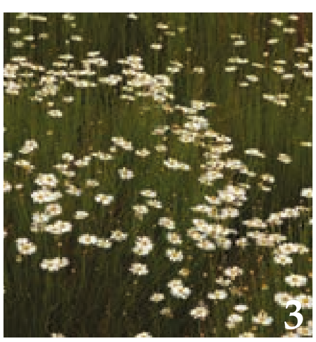
Semi-permanent wetlands (shallow)



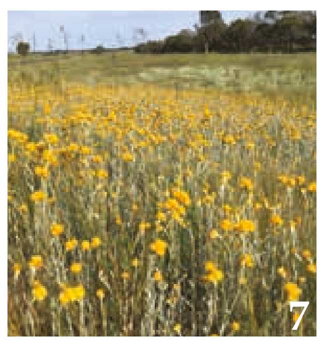
Herbfields

Kangaroo Grass plain





1. *Craspedia glauca*
2. *Eleocharis pusilla*
3. *Brachyscomb basaltica*
4. *Calotis scapigera*
5. *Cullen tenax*
6. *Diuris basaltica*
7. *Chrysocephalum apiculatum*
8. *Stackhousia monogyna*
9. *Caesia calliantha*
10. *Convulvulus erubescens*
11. *Ptilotus spathulata*
12. *Podolepis* sp.



Grassland wildflowers: 1. Hoary Sunray *Leucochrysum albicans*, 2. Red Parrot-pea *Dillwynia hispida*. 3. Blush Bindweed *Convulvulus erubescens*, 4. *Ptilotus macrocephalus* 5. Button Wrinklewort *Rutidosis leptorhynchoides*, 6. *Diuris* sp. 7. Small Vanilla-lily *Arthropodium minus*, 8. Bushy Parrot-pea *Dillwynia ramosissima* 9. Small Golden Moths *Diuris basaltica*, 10. Basalt Sun-orchid *Thelymitra gregaria* © Stephen Platt.

Plant life

PLANTS HAVE adapted to this tough, seasonally dry, fire-prone, but by Australian standards relatively nutrient-rich, environment. To survive here you need strategies to conserve water and 'duck for cover' when a fire occurs, which it does often. Most grassland species grow during the cool, wetter months from autumn to spring. For many species, growth buds are at the soil surface (hemicryptophytes) where they can avoid fire, and the mouth of hungry grazing animals. Some get completely out of the way and store water and nutrients for next year's growth in an underground, carrot-like tuber. Fire will consume above-ground parts but the below-ground plant lives on and resprouts rapidly.

Most grassland plants (over 95%), are long-lived perennials.[206]

Though the dominant Kangaroo Grass (*Themeda triandra)* is barely half a metre tall, the tussock it forms can be very long-lived (in excess of 50 years). They are the trees of this 'forest in miniature' with deep root systems that can get down to water trapped in bedrock cracks metres below the surface. Highly competitive, in the absence of disturbance Kangaroo Grass can crowd out other species by spreading its leaves to form a continuous thick mat. Kangaroo Grass has a different photosynthetic pathway, called C4, to other grasses which allows it to germinate and grow in the hot summer months whilst many other C3 species typically germinate and grow following autumn rains. Though bathed in light, competition for this key resource is still a major ecological factor in grassland ecosystems.

Tussock-forming spear (*Austrostipa* spp.) and wallaby (*Rytidosperma* spp.) grasses are also common but they tend to occupy the less favourable sites thus avoiding direct competition with Kangaroo Grass. They are highly tolerant of moisture and nutrient stress.

Between the tussocks grow a wide range of herbs, such as Button Wrinklewort (*Rutidosis leptorrhynchoides*), and small shrubs including Spiny Rice-flower (*Pimelea spinescens)* and Bitter Pea (*Daviesia* spp.). They have relatively thick, sinuous, rope-like roots that travel deep into the soil, where water can be found, and resist the shearing forces of cracking clay. Herbs add colour to the grassland through their vibrant flowers.

Tuber-forming species (geophytes) are numerous and include Murnong or Yam Daisy (*Microseris scapigera, M. walteri, M. lanceolata*), Vanilla Lily (*Arthropodium* spp.*)*, Chocolate Lily (*Arthropodium strictum)*, Blue Grass Lily (*Caesia calliantha),* Bulbine Lily *(Bulbine bulbosa),* Early Nancy (*Wurmbea dioica)*, Austral Storks-bill (*Pelargonium australe)*, Blushing Bindweed (*Convolvulus erubescens)* and orchid species, water ribbons and bullrushes. They are our native versions of carrots and potatoes.

Yam Daisy (*Microseris scapigera*) showing the underground tubers that form when, as summer approaches, the above-ground plant dies back. This species was a staple food of Aboriginal people. Source: Wikipedia Commons © Editor Andrew CC BY-SA 4.0.

Aboriginal women digging native yams at Indented Head, Victoria. George Augustus Robinson, the Protector of Aborigines from 1839 until 1849, noted in 1840 that the basalt plain known as Spring Plains was covered with 'millions of Murnong (*Microseris lanceolata*)', a dandelion-like native daisy, the tubers of which were a major staple food. In 1841, he described women 'spread over the plain as far as I could see them, collecting [roots] – each had a load as much as she could carry'. Drawn by J. H. Wedge (1835). Image source: State Library of Victoria.

A few, short-lived (annual) species take advantage of the space between grass tussocks, particularly following disturbance, including groundsels (*Senecio* spp.) and Hoary Sunray (*Leucochrysum albicans*). They complete their life cycle quickly. Their characteristics include a capacity to disperse widely to newly disturbed sites, to grow quickly and produce seed before summer removes life-sustaining water. Hoary Sunray does this via its wind-dispersed, 'parachute-headed' seeds.

Native Yam has characteristic drooping flower heads.
[207]

Wind dispersed seed of Hoary Sunray.[208]

The beak of the Long-billed Corella (*Cacatua tenuirostris*) is well-designed for digging plant tubers from the soil.

Emu Foot (*Cullen tenax*), is a pea that is listed as 'endangered' in Victoria.

Plants as design inspiration

Plant burrs inspired the invention of velcro. In 1941, after noticing burrs stuck in dog fur, Swiss engineer George de Mestral examined them under a microscope. He observed many tiny hooks that could latch onto hair and other substances. The name ‘velcro’ comes from the French words *velours* (velvet) and *crochet* (hook).[209]

On gradual slopes, where grasses do not dominate, herb communities can be prolific and the display of colourful flowers in springtime extraordinarily beautiful.

Competition for resources and varying strategies to exploit them, lead to a diversity of plant species.

Pollination, flowering, dispersal and recruitment

GRASSES USE the wind for pollination. On the flat, grassy plains, wind is never in short supply.

Invertebrate pollination in grasslands is carried out primarily by beetles, flies, native bees, moths and butterflies.

The types of plants common in grasslands correspond with their pollinators. Daisies have a composite flower head made up of many tiny flowers. This is ideal for butterflies and flies, which can quickly probe each little ‘pot of nectar’ with their long tongues. Pea and orchid flowers have a small ‘landing pad’ at the front. When an insect such as a bee lands on a pea flower, the pad deflects downwards exposing the pollen which gets dabbed onto the insect’s belly.

A Caper White Butterfly (*Belenois aurota*) attending Hoary Sunray (*Leucochrysum albicans*). © Stephen Platt.

Many grassland species have seeds with hooks or burrs that catch on passing animals and facilitate dispersal. Burr Daisy (*Calotis lappulacea*). © Steve Taylor CC 0 4.0.

Beetles are important grassland pollinators. This species is on Common Everlasting (*Chrysocephalum apiculatum*). © Stephen Platt.

Featherheads (*Ptilotus macrocephalus*) is probably pollinated by nocturnal moths. © Stephen Platt.

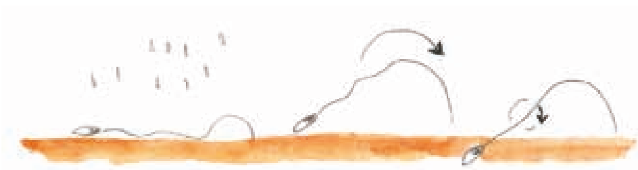
Red Parrot-pea (*Dillwynia hispida*) occurs in grasslands west of Melbourne and is widespread in western Victoria. © Stephen Platt.

Native (Halictid) bee pollinator visiting an endangered Small Golden Moths orchid (*Diuris basaltica*). These bees live in a burrow in the ground. The orchid mimics nearby nectar-producing species tricking the bee into visiting it.[210] © Stephen Platt.

The timing of flowering is earlier than most other ecosystems as hot, dry summer conditions that could affect seed development can arrive early. Kangaroo Grass seed typically falls around Christmas Day. The intensity of flowering is dependent on recent rainfall and the time-since-the-last-fire. Peak flowering occurs in the years immediately post-fire.

Plants have many means of dispersing their seeds. Many grassland species' seeds are adapted with spurs, spines, burrs and hooks to latch onto the fur and feathers of passing animals, thereby catching a ride to new places. Others have structures that catch a breeze so they can fly away from the parent plant. Yet others are carried away by invertebrates, especially ants. One only needs to walk through a grassland wearing socks in summer and you will experience the capacity of seeds to latch on and not let go. Though most seeds fall close to the parent plant, some seeds can move large distances. Birds, such as Emu and Australian Bustard, were probably important in long-distance seed dispersal.

Kangaroo Grass and Spear Grass seed buries itself in preparation for germination. On wetting, the corkscrew-like 'awn' twists and lifts up like a drill rig and, as the awn continues to unwind, the seed is drilled into the soil. Geraniums and Stork's Bill (*Erodium*) also have awns that help their seeds to penetrate the soil crust.



Like a spear that throws itself, Kangaroo Grass seed is adorned with a long, curved awn that helps to bury its seed.
© Stephen Platt.

Two strategies for germination have been identified in the herbs. Either the seeds all germinate in response to rainfall no matter how thick the canopy of grass cover might be (most grassland daisies) or the seeds remain dormant until conditions are suitable and dormancy broken.

Seed dormancy may be broken by environmental conditions. Some dormant species exude a gel (are myxospermous) when their seed becomes wet which may stop the seed drying out and help with contact to the soil surface (e.g., *Goodenia* spp.). Yet other plants have seeds that only germinate following specific events such as damage to the seed coat (e.g., *Convolvulus angustissimus*) or burial then exposure to light including many lilies and some peas such as Emu-foot (*Cullen tenax*). These mechanisms ensure that seeds germinate with the best possible chance of success.

Most grassland species lack an ability to persist for long in the soil seed bank. Autumn rainfall leads to germination of most seeds but the vast majority of seedlings will die. In a tightly held system like this, where perennial species dominate, there is little free space and the resources that go with it, particularly summer water supply.

For most species, recruitment is primarily tied to the timing and amount of rainfall. It may be that the decline and death of existing mature plants creates the gap that is needed by a juvenile plant to survive to adulthood.

The lichens and mosses growing on the soil surface (cryptogamic crust) are important in soil moisture retention, in assisting germination, and as food for invertebrates and may help to retard weed invasion.[211]

Large-headed Fireweed (*Senecio macrocarpus*) at Bannockburn is listed as endangered. © Stephen Platt.

Chocolate Lily and Creamy Candles (*Stackhousia monogyna*) at Cobra Killuc. © Stephen Platt.

Disturbance

Fire occurred as a result of lightning strikes and Aboriginal burning. In grassland ecosystems, fire was very frequent, as often as once every three to seven years. It was all-consuming and fast-spreading but not particularly intense. Too wet to burn in winter, grasslands generally do not burn until summer temperatures dry out the sward. Accumulation of at least 70% dead leaves, of prior year's growth, is generally needed to sustain a fire.[212] In higher rainfall areas, this can be achieved within a few years post fire but takes longer in drier regions or in periods of drought.

We can imagine that a pattern of fire initiated by lightning strikes existed across the grasslands. It produced a mosaic of patches at different stages of growth. There would be 'open' areas immediately following fire to 'dense' areas as the years without fire accumulate. Each patch would have unique characteristics that could be exploited. Recently burnt areas would provide germination opportunities for plants. Whereas invertebrates, food for many animals, may well have been more numerous in the unburnt, dense, grass swards where moisture, shelter and food is more abundant.

Fire frequency affects which species of grass are dominant at a site. Frequent fire (four to eight years) favours Kangaroo Grass (*Themeda triandra*), whilst less frequent fire favours Poa (*Poa sieberiana*).[213]

Whilst most species can cope with frequent fire, the few fire-sensitive plants that exist here, such as Drooping She-oak (*Allocasuarina verticillata*) and Honeysuckle (*Banksia marginata*), usually occur in fire refuges such as rocky areas and along creek lines.

Grazing by large herbivores such as kangaroos, which keeps the vegetation open, and digging by species such as bandicoots, which aerates the soil and creates small patches of bare ground that can act as germination sites, are also important in maintaining grassland processes.

Aboriginal use of fire

This is a food-rich environment for aborigines seeking underground tubers. Clearing by fire of the dense thatch produced by the dead leaves of grasses, which accumulates over several years, would have opened up the ground layer. New spring shoots of this year's resprouting tubers, and dead above-ground remains of plants that flowered last summer then retreated underground in autumn, would have been much more visible in the first couple of years after fire. Thus, use of fire to gather tubers would have provided a significant benefit to aborigines occupying this ecosystem.

Silver Banksia (*Banksia marginata*) grows in small stands across the basalt plains. Aboriginal people soaked the flowers in water to remove the nectar and make a sweet drink.
© Stephen Platt.

Herbaceous native grassland. © Stephen Platt.

Animal life

SO, WHAT type of animals would you expect to find on an open plain? Certainly not those that depend on trees such as gliding possums and honeyeaters. In grasslands, danger lurks in the sky above in the form of birds of prey including Wedge-tailed Eagles, kites, falcons and kestrels that can hunt freely without the obstruction of tree limbs. At ground level, there are few shrubs to hide in. Predators, including the Dingo, Eastern Quoll and numerous snakes, hunt on the land surface. Grassland animals must be able to cope with this level of exposure to predators.

The animals of the plains tend to be large grassland specialists, such as kangaroos and Emu, that are fast or strong enough to deal with predators, or smaller than grass height, hard to see and able to use rocks and soil cracks for shelter such as dunnarts and small lizards.

As on the African savannas with their wildebeest and antelope, and the South American Pampas with Guanaco and Rhea, large grazing animals and flightless birds were abundant on the Victorian grasslands.

Long migrations, such as those on the African continent, did not occur. This may be due to the east-west orientation of the Victorian Volcanic Plains, which has relatively even climate. In contrast, the north-south orientation of grasslands in Africa leads to a significant rainfall gradient that drives the migration.

With abundant food in the form of grasses, nearby wooded areas for rest and the ability to move quickly away from predators (up to 64 km/hr[214]), kangaroos are ideally suited to these habitats. Mobs of our largest marsupials, the Eastern (*Macropus giganteus*) and Western Grey Kangaroo (*Macropus fuliginosus*), would rest in wooded areas during the day and graze on the grasslands primarily in the early morning and evening (crepuscular), and overnight. Grass isn't particularly nutritious, so you need to eat plenty of it to gain enough energy to survive and it is hard on teeth so kangaroos grow new molars at the back of their jaw that move forward to replace those that wear out.

Eastern Grey Kangaroos breed throughout the year. A dominant male will court his females, trailing them and stroking their hind quarters while softly grunting. One tiny (0.8 gram) young is born. It immediately makes a perilous journey across her fur-covered body to reach the pouch where it will live for 10 months before become sexually mature at 20 months of age.[215] During the time that she has a young in the pouch she will mate again but the embryo will remain in stasis until the pouch is emptied. This is a strategy designed to maximise reproduction in an environment that swings between plentiful times and drought.

Eastern Grey Kangaroos (our 'deer') utilised the vast grass resources of the plains. © Duncan McCaskill. CC

Eastern Quolls (The 'fox') are medium-sized predators that were once common across Victoria's grasslands, but unfortunately are now extinct on mainland Australia. © Brett Vercoe. CC-BY-NC 4.0 (Int).

Light and dark colour forms of Eastern Quoll occur within the same litter. © Brett Vercoe. CC-BY-NC 4.0 (Int).

Eastern Barred Bandicoots (The 'rabbit') dig for underground tubers and fungi; an activity the exposes soil and advantages some plants. © J J Harrison. CC SA 3.0 Unported.

A Fat-tailed Dunnart (The 'mouse') shelters in a burrow under one of the numerous rocks that scatter the surface of native grasslands. © Andrew Bennett (above), Stephen Platt (below).

Medium-sized mammals were also abundant. Eastern Quolls (*Dasyurus viverrinus*) are daintier than their forest-dwelling Tiger Quoll cousins. At European settlement they were so common on the grasslands that many landholders regarded them as a pest. In 1862, Horace William Wheelwright wrote that "*The little native cat is one of the most prolific animals in the bush, and I have often killed six young ones in a nest. The native cat is a small beast of prey, very destructive to birds, especially poultry, and eggs*." Populations crashed not long after European settlement, possibly due to diseases carried by introduced cats and foxes.[216]

Eastern Quolls are solitary predators that mainly eat invertebrates. They also eat small mammals, birds and reptiles, and can kill prey as large as a bandicoot. Quolls rest during the day in a burrow. Females can give birth to up to twenty young. Only the strongest will manage to attach to one of the available six to eight teats.

The Eastern Barred Bandicoot (*Perameles gunnii*) requires structurally complex habitats with dense cover for nesting, adjacent to more open areas suitable for feeding. They appear to prefer areas with high soil moisture content, such as swampy depressions, poorly drained areas and along creek margins. They forage at night for invertebrates and dig with their powerful claws for vegetables from dusk to dawn. They can turn over 13.5kg of soil per night. Their digging activity helps to maintain soil health and create sites for seedlings to establish. During the day, Eastern Barred Bandicoots rest in a grass-lined nest on the soil surface. They move between nests regularly. Though they live for just a few years, they breed at a phenomenal rate producing up to five litters of two to three young each year. After three months in the pouch, the young become independent and disperse. This ecologically important species is extinct in the wild in Victoria though it survives in Tasmania. It has an active Victorian reintroduction program.

Being small in size has its disadvantages for the Fat-tailed Dunnart (*Sminthopsis crassicaudata*) a mouse-sized, carnivorous marsupial that lives in a burrow, usually beneath a large basalt rock. Not only are they bite size for many predators but their body size is insufficient to keep warm in very cold weather. They manage by huddling together as small groups during winter, entering a low metabolic state called torpor and, on fine days, sunning themselves in the early morning. With razor sharp teeth, this dunnart forages at night for invertebrates and small reptiles. The tail stores fat for use over the lean winter months. Females give birth to 6–10 rice-grain sized babies at a time and may have two litters in a season. Most predators on the plains can make a meal out of a Dunnart. Note the big ears and large eyes to help with avoiding them. Their tail is used to store fat reserves.

Emu were found across the grasslands. This mob are probably all from the same clutch. © Stephen Platt.

Built like a mobile haystack, mobs of Emu (*Dromaius navaehollandiae*) wandered across the plains searching for plants, seeds and invertebrates. All those feathers have a purpose. Emu can spend long periods foraging in direct sunshine, due to the protective insulation of their two-fingered feathers. These are so effective, Emu only need small (<330 ml) quantities of water to replace a day's sweat, a real advantage when living on a plain devoid of trees.

Out on an open plain, Emu are at risk from predators such as Dingo, Wedge-tailed Eagle (chicks) and other birds of prey (eggs). As the second largest bird in the world, at around 40kg, with a running speed of 50km/hr, few animals would dare take on an adult Emu. Their scientific name *Dromaius navaehollandiae* means the 'fast-footed bird of New Holland'. Though they have residual wing stubs, Emus are flightless (ratites).

In a gender role reversal, the female Emu courts the male with deep booming sounds. She will lay 5-15 giant, blue-green eggs per clutch – but there's a catch for him. He has been duped. The male Emu is a cuckold (husband of an adulteress). Over half the eggs he sits on for the next 55 days may not be his own. Not only that but one in ten may not be from his female partner and another tenth may be of neither 'parent' (they belong to a brood parasite).[217] The young he raises will remain with their father until fully grown. Thus, a mob of Emus may all be from the same clutch if not the same father or mother.

On July 10, 1836 the explorer Major Mitchell records in his diary "…we killed two emus, one of which was a female and esteemed a great prize, for I had discovered that the eggs found in the ovarium were a great luxury in the bush, and afforded us a light and palatable breakfast for several days".[218]

Emu eggs are very tough-shelled. This probably helps them to survive egg predators and the heavy feet of their parents but presents a challenge to chicks wanting to hatch.
© Stephen Platt, Hattah.

There was a time when you could see Australian Bustard's nearby to Melbourne. © Steve Parish.

The male Plains Wanderer incubates the eggs and so it is his female mate (shown) that is brightly coloured.
© Carlos Sanchez CC NY-BC 4.0 (Int).

'Bush Turkeys' (Australian Bustard, *Ardeotis australis*) were also relatively common in grasslands. In the 1850s, Horace William Wheelwright recorded that "I have seen as many as twenty-seven feeding together in the wide open country towards Gelong"[sic].[219]

Australian Bustards blend into the background for most of the year but not when breeding. In the breeding season he clears a display area and proceeds to inflate his plumed throat sack and emit a loud boom like a lion's roar, repeated every 10 or so seconds. Not only that, he throws his head back, drops his wings and spreads his tail in a performance aimed at impressing onlooking females. These elaborate performances allow males to establish their prowess without the need for direct conflict with other males.

With few perches for birds, ground specialists such as the quail-sized Plains Wanderer *(Pedionomus torquatus)* are found in the grasslands.

Unlike most birds, it is the female that has the brightly coloured plumage. He incubates the eggs and so needs to be well camouflaged to avoid predators. She may mate with several males in a season.

Plains Wanderers, as their name suggests, can fly and migrate widely across south eastern Australia searching the plains for their food of seeds.

Under threat, Plains Wanderers freeze in order to hide by blending into their habitat. Anyone who has searched for a Plains Wanderer will know how difficult they can be to find and, once discovered, how easy to photograph.

The plains are dotted with short-term, shallow wetlands interspersed with deeper perennial wetlands and permanent lakes.

Brolgas have a breeding home range of 70–523ha. Pre-fledged chicks move up to two kilometres from their night roost wetland and may use several wetlands.[222] © Mc, A. Andrew. CC-BY-NC.

Large enough as an adult to defend itself against most predators, the Brolga (*Antigone rubicunda*) breeds in large (16ha), shallow (25cm deep) freshwater marshes and meadows with extensive emergent aquatic vegetation.[220] They have a wide diet including vegetation, frogs, small fish and a range of invertebrates, including freshwater molluscs, crustaceans and insects, even mice.

Paired for life, Brolga breed from July–December. Elaborate courtship displays involving leaping, wing-flapping and loud trumpeting are a prelude to building a nest mound. It is made of vegetation and surrounded by water. Both adults incubate the eggs and care for the young birds.

This species has declined due to loss of wetland habitat, chick predation and collisions with powerlines and fences.

Looking something like plaited, dried grass, the Striped Legless Lizard (*Delma impar*) is rarely seen although on sunny days it will bask in the cradle of a grass tussock or on an exposed rock. The tussock grasses that provide it with protection from predators are also the source of a major threat, fire. Grass fires spread quickly. Escape by outrunning the fire is not an option. In summer, the cracking clay soils of the grasslands provide the opportunity for lizards to shelter below-ground level away from fires and circling birds of prey. Basalt rocks also provide protection from predators. Striped Legless Lizards eat crickets, spiders and moths.[221]

Striped Legless Lizard. © Peter Robertson, Wildlife Profiles.

Look carefully and you will see a Striped Legless Lizard hiding in this soil crack. © Melissa Doherty.

Little Whip Snakes shelter in soil cracks and beneath rocks.
© Stephen Platt.

Grasslands are excellent habitat for snakes. Tiger Snakes (*Notechis scutatus*) occupy the wetter areas where they feed predominantly on frogs. Other small vertebrates including birds are also eaten. Up to 37 live young are born in late summer/autumn. Eastern Brown Snakes (*Pseudonaja textilis*) are active during the day seeking small mammals, such as dunnarts, and reptiles as prey. Up to 30 eggs are laid in deep soil cracks. The Little Whip Snake (*Parasuta flagellum*) is a secretive nocturnal species that feeds on lizards, mainly small skinks. It shelters beneath a rock or in soil crevices. They produce up to seven live young. When handled they emit a foul smell presumably to ward off predators.

Frogs inhabit the numerous waterbodies on the plains. The endangered Growling Grass Frog (*Litoria raniformis*) often feeds on other frogs, including cannibalising smaller frogs of the same species. They prefer permanent wetlands that have abundant reedy vegetation on the margins and that are nearby to other wetlands.

Common Spadefoot Toads (*Neobatrachus sudellae*) survive dry periods by burrowing into the soil. They cocoon themselves in a chamber underground and slow down their metabolism (aestivate). After rainfall they emerge. Male frogs croak noisily seeking to attract a mate and warn off other suitors. They are omnivores, eating vegetation and large invertebrates such as grasshoppers.

Growling Grass Frog. © Peter Clark. CC-BY.

Blue-banded Bee. © Vengolis CC BY-SA 3.0.

Common Spadefoot Toads remain buried for most of the time.
© Owen Lishmund. CC-BY-NC 4.0 (Int).

Studies of grassland invertebrates has found that each grassland site is very different from another. There is also great diversity. One study found 234 species in 46 sites, mainly beetles, ants, grasshoppers and bugs.[223]

Native bees are important pollinators in grasslands. For example, the Blue-banded Bee (*Amegilla cingulate*), undertakes specialised ‘buzz’ pollination of grassland plants, such as the Matted Flax Lily (*Dianella amoena*). Most native bees are solitary, live in soil burrows and fly relatively short distances of only several hundred metres.

The Golden Sun Moth *(Synemon plana)* is found in grasslands with a high cover of wallaby (*Rytidosperma* spp.) and Spear (*Austrostipa* spp.) grasses. Aspect and landscape position also influence where it is located.[224] These moths have also been found in exotic pasture.[225]

Adult moths are unable to feed and live only 2–5 days. After mating they lay up to 200 eggs at the base of a grass tussock. Three weeks later the eggs hatch and the larvae burrow down to feed on grass roots. After six weeks (or longer in harsh years) they dig to the surface and fly away as adults. Females flash their bright orange wings to attract males.

Native bees are attracted to this Golden Cowslip Orchid (*Diuris behrii*). © Stephen Platt.

An endangered Golden Sun Moth (female). It is unusual in having clubbed antennae and not feathered or comb-like.
© Leo, Encyclopedia of Life Images Flikr Group. CC BY-NC-SA 2.0

Cover image interpretation: The absence of trees and abundance of native grasses and herbs indicates that this is a native grassland remnant (in this case on a roadside). The open spacing between plants suggests that fire has been recent and regular, removing the old, mat-forming leaves of the grasses. Flowering occurs earlier in this system to avoid early onset of dry conditions in summer. This appears to be peak flowering which suggests a scene from October–November.

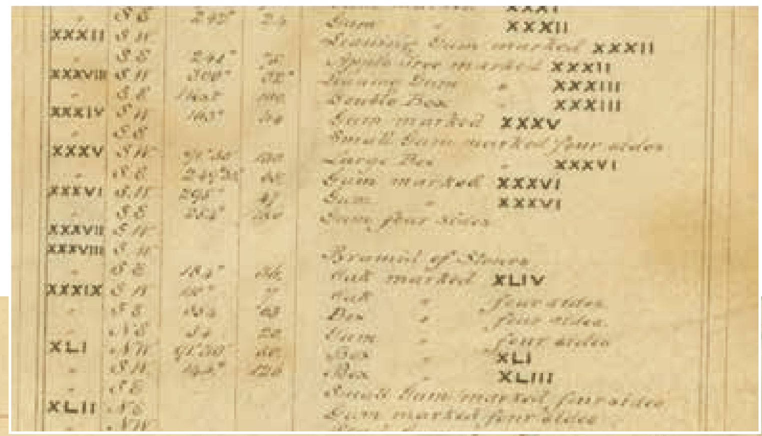
Where to see this ecosystem

- Baababi Marning (Cooper Street) Grassland
- Ngarri-djarrang (Central Creek) Grassland Reserve
- Denton Avenue Grassland Reserve
- Isabella Williams Grassland Reserve
- Arcade Way Reserve
- Cypress Views Grassland Reserve
- Evans Street Wildflower Grassland
- Mortlake Common Flora Reserve
- Dunkeld Arboretum Grassland
- Terrick Terrick N.P.
- Mooramong (National Trust)
- Imaroo Grassland Reserve
- Derrimut Grassland Nature Conservation Reserve
- Western Grassland Reserve (in development)
- Serindip Sanctuary
- Mount Rothwell

Evidence for treelessness and William Wedge Darke

GIVEN THAT grassland landscapes have been highly modified and are now largely covered in exotic pastures, how do we know that they were treeless? Early explorer diary entries contain numerous references to treeless grasslands. For example, in 1802 Matthew Flinders recorded that the Werribee Plains were "covered with small-blade grass but almost destitute of wood, and the soil was clayey and shallow". John Batman (1835) described plains "…with scarcely any timber, and covered with Kangaroo grass eight and ten inches high. This I think is the average. Most beautiful sheep pasturage I ever saw in my life".[226]

In the early 1830s, William Wedge Darke, as assistant surveyor to Robert Hoddle, carried out some of the first surveys of the new town of Melbourne including laying out the streets ready for auction. He lived in a two-roomed caravan with a piano on the south side of the Yarra River dubbed 'Darke's Ark'. It was drawn by bullocks to wherever he was surveying. Darke produced maps of the area east of Melbourne showing in considerable detail exactly where trees grew, such as the River Red Gums along watercourses. He also noted shrubs such as Honeysuckle (*Banksia marginata*) and She-oak (*Allocasuarina verticillata*) which were used to mark allotment boundaries. Darke was the first European settler to cut a track through the tea trees to the beach south of Melbourne where he parked his caravan and hoisted a barrel on a pole to note the location of his track, after which 'Sandridge' was named.[227,228]



Early survey plans of land in Victoria include notes on the vegetation such as "grassy plains thinly wooded" and the species used as allotment corner markers such as Gum/Box (*Eucalyptus* sp.), Oak (*Allocasuarina verticillata*) and Honeysuckle *(Banksia marginata)*.

Source: Public Records Office of Victoria. Plan of the Parishes of Derrimut and Maribyrnong in the County of Bourke. 1842. Sydney D17: Derrimut.

Getting to know our mammals

1. Agile Antechinus © Brett Vercoe. **2. Red Kangaroo joeys in pouch** © Chris Lindorff.
3. Eastern Horseshoe Bat © Brett Vercoe. **4. Echidna** © Zach Lim.

Getting to know our mammals

THERE ARE 144 native species of mammal known from Victoria.[229] Nine species are extinct in the State and 49 are considered threatened.[230] Species of terrestrial mammal in the Critical Weight Range (35–5500g) are particularly vulnerable to introduced fox and cat predation and have declined markedly. Some species, such as Eastern Grey Kangaroo, have increased noticeably as humans create ideal habitats through agriculture.

Types

Mammals	Taxa	Threatened	%
Mammals (Terrestrial)	105	19	18
Marine	39	5	13
Terrestrial (introduced)	23	0	0
Total (native, incl. marine)	**144**	**24**	**17**

The terrestrial mammalian fauna consists primarily of large grazers (e.g., kangaroos); medium-sized browsers (e.g., wombat, wallaby); small, ground-level insect eaters (insectivores e.g., Kultarr, antechinus') and generalists (omnivores e.g., bandicoots, native rats), arboreal species, (e.g., koala, possums and gliders, phascogale) and bats, which is the largest group. Two monotreme oddities occur here and are fairly common (Platypus, Echidna). In the sea there are whales, dolphins and seals.

As a result of Australia's long isolation, we have a relatively large number of marsupials (mammals with a pouch, but lacking a placenta, that give birth to young in the early stages of development). © Brett Vercoe. CC BY-NC.

Mammals have hair, sophisticated breeding systems and produce milk to feed their young. They also vary in anatomical features (skull, heart, diaphragm, teeth, jaw) from other groups.[231]

Mammals (*mammae* is Latin for breast or teat) include monotremes, marsupials and placentals. There are just two species of egg-laying monotreme (Platypus, Echidna). Marsupial mammals give birth to naked young and have a pouch (*marsupium* is Latin for pouch) in which the undeveloped young can continue to grow safely. In contrast, placental mammals have a placenta that allows internal development in a womb and young to be born at a more advanced stage.

Platypus in the Yarra River 20km from Melbourne's GPO.
© Stephen Platt.

Monotremes – Echidna and Platypus – are survivors of an ancient lineage of egg-laying mammals with links to reptilian ancestors. They live vastly different lives. Short-beaked Echidnas are terrestrial and feed on ants whilst platypus feed on invertebrates in freshwater streams. They differ from other mammals in laying eggs, lacking teats to suckle young and some anatomical features.

Marsupials – account for most other native species in Victoria. They include:

- **Dasyurids** are mostly small, ground insectivores. They tend to be high-energy, active feeders. Life spans are short and young plentiful. The dasyurid family includes antechinus, dunnart, ningaui, kultarr and planigale as well as larger members including quoll and phascogale.
- **Peramelids** are better known as bandicoots. They are medium-sized, nocturnal and most are omnivores eating such things as worms, insects and fungi. By cultivating soil via digging and spreading fungal spores, they contribute to ecosystem health.
- **Diprotodonts** – include wombat, koala, possums and gliders, bettongs, potoroos, kangaroos and wallabies. Kangaroos, as our largest grazing

Kultarr (*Antechinomys laniger*). © Tim Bawden. CC BY.

Eastern Barred Bandicoot. © Ken Walker. CC BY-NC-SA

Little Red Flying-fox (*Pteropus scapulatus*). © Juliet Lowther.

animal. They rely on grasslands/grassy woodlands. Browsing animals such as the Black-tailed Wallaby consume woody plants, twigs, leaves and other above-ground vegetation. They affect the mid-storey vegetation in forests and woodlands. Potoroos contribute to ecosystem health by spreading spores of fungi that are needed by trees.

Placental mammals include:

- **Eutherians –** represented by microbats, flying foxes, rats and mice and a range of introduced species.

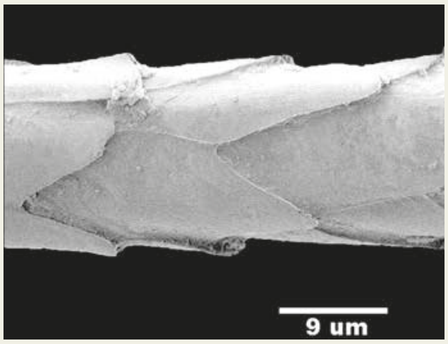
  Bats are the largest group, though their night-time activity means they are one of the least well known. Ecologically they play important roles as pollinators and dispersers of seeds, and as predators of small invertebrates. Bats are active at night and fulfil the ecological role that birds occupy during the day. Their active resting heart rate is around 400 beats/minute, rises to 1000 when foraging and can drop to 40 when in torpor. Most bats use echo-location to navigate and find food and water. They are able to reduce their body temperature to within a few degrees of air temperature. In winter they go into a state of shallow hibernation. A South-eastern Free-tailed Bat (*Ozimops planiceps*) in torpor was found to breathe once every 80 minutes. Most female bats mate during autumn but do not conceive until spring when more food is available. Sperm is stored over winter. Few bats are active in winter. Microbat activity drops off when air temperatures drop below 5°C. Those that are active in the cold are most likely to be males looking for females to mate with. Bats drink 'on the wing' in a similar fashion to swallows. They have good eyesight. Mothers protect their young, rescuing them when first flights fail.

  Common Bent-wing Bats (*Miniopterus schreibersii basanii*) live up to 20 years in the wild. They have been recorded travelling 200kms from a maternity cave to feeding grounds in one night!

- **Mice and Rats**, of which there are native and introduced species, live across the state from the coast to the alps and Mallee. They are often prey to larger species.

  Many mammals are nocturnal and so rarely seen by humans. Detecting mammals at night can be difficult. New techniques, such as camera traps and infrared cameras, have improved our ability to know which and how many mammals are present. The unique qualities of mammal hair, often found in droppings, allow experts to determine the species. Transmitters attached to animals have allowed us to track their movements in detail. Knowing how to identify tracks and traces is perhaps the best way for most people to detect what mammals are around (see recommended reading).

Broad-toothed Rat (*Mastacomys fuscus*). © Ken Green.



Imbricate scales on the hair of a Sugar Glider (electron microscope). © CSIRO CC 3.0

The 'lawn' beside this estuary at Wilson's Promontory is 'mown' by marsupials (a 'marsupial lawn'). © Stephen Platt.

Communication

Mammals use a wide variety of communication methods including voice, facial expression and posture, scent-marking and smell, signposts (e.g., wombats leaving piles of poo) and brands (e.g., bark chewing and rubbing). Grooming, stroking and rubbing may initiate mating. Mammals have excellent eyesight, echolocation (bats), sense of smell and touch.

Feeding

There are herbivores (e.g., kangaroos), carnivores (e.g., quolls), insectivores (e.g., most microbats) and omnivores (bandicoots). Koalas specialise in fibrous and toxic eucalypt leaves and their gut is especially adapted to process them. Echidnas feed on ants. Fungi make up a large proportion of the diet of potoroos and bandicoots.

Movement

The majority of mammals live in defined territories, defending their resources against rivals. Spot-tailed Quolls range over 2,500ha, whilst Yellow-footed Antechinus' range up to 0.6ha. Gliders and possums tend to move aerially or through the canopy. A Sugar Glider was recorded gliding 80m across the Murray River. Bats are excellent flyers and can be extremely acrobatic in their flight movements allowing them to follow the erratic flight of a moth or other prey. There are specialist swimmers such as platypus, dolphins and whales. Others can swim when necessary, including for example, Koala and Echidna. Males often make large movements looking for a mate. A Brush-tailed Phascogale was recorded making a 15km movement during the breeding season.

Kangaroos are the only large animals to get around by hopping. Hopping at moderate speeds (~40km/h) is more energy-efficient than alternatives and allows for travel over obstacles rather than pushing through them. Over 70% of potential energy is stored in the elastic tendons of the hind legs. Speeds of up to 64km/hr can be achieved.

Courtship and breeding

Courtship rituals among mammals can be complex, reflecting a high level of intellect. Males may engage in ritual displays of fitness (e.g., male kangaroos 'boxing'), Platypus courtship occurs over six weeks. The male will bite and hold on to her tail and, if she accepts him, she will do likewise as they swim in a circle. They also dive, roll sideways and swim together before mating. Courtship may also be minimal as happens when a female microbat is in torpor when mated by a male. She will store his sperm until spring when she releases an egg.

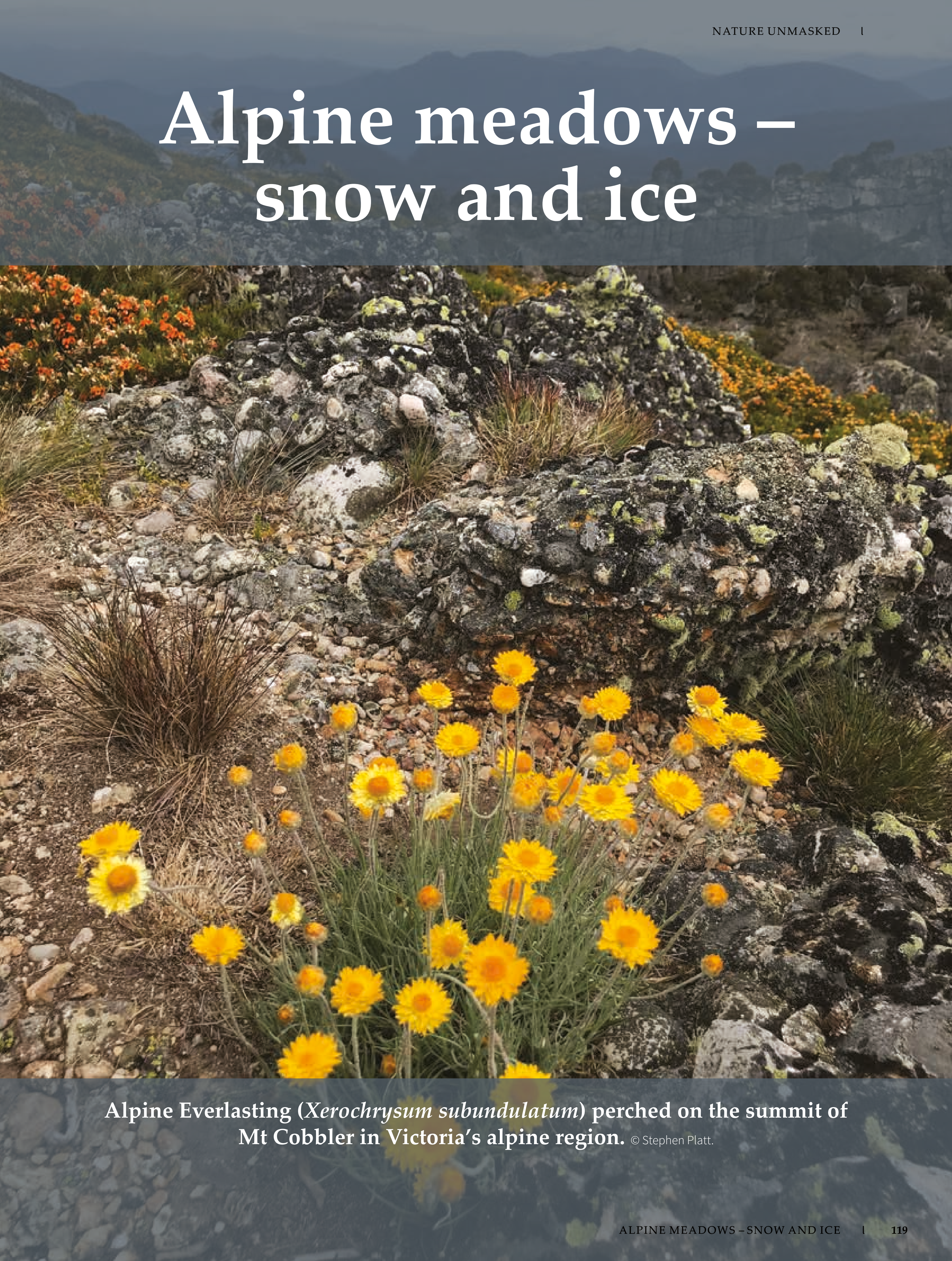
With the exception of monotremes, mammals give birth to live young. This avoids an egg-laying phase and the need to remain near the 'nest' and guard eggs until they hatch. Parental care is common to most mammals. Milk, which only mammals produce, is a rich source of energy that supports growth.

Ecological role

Mammals, through grazing and browsing, influence plant reproduction and forest boundaries. Some species are important pollinators. They may be predators or prey and influence forest health through activities such as spreading fungi needed by trees.

◀ A Pied Currawong (*Strepera graculin*) attacking an Eastern Ring-tailed Possum (*Pseudocheirus peregrinus*) in its drey (domed night shelter). The Currawong tried to grab the possum's tail and persisted for over 20 minutes. In this instance the possum survived. Pied Currawongs switch their diet from fruits in the non-breeding period to insects and birds when they are raising young.[232] © Juliet Lowther.

Alpine meadows – snow and ice



Alpine Everlasting (*Xerochrysum subundulatum*) perched on the summit of Mt Cobbler in Victoria's alpine region. © Stephen Platt.

Alpine meadows – snow and ice

***THE LONGEST** monitoring study in Victoria, a place where trees don't grow, a flower that lovingly hits visitors on the head, home in a river of boulders, a skirt for snow, long-lasting moth cakes, ancient plums, cave women, a whistling frog, a love cave – its cold up in the alps but not uninhabited.*

Introduction

IN LATE autumn, as snowflakes fall and settle among the Snow Gum woodlands in the mountains of Victoria, it is eerily silent but for perhaps the echoing call of a Pied Currawong or sprightly alarm of a pair of Crimson Rosellas. This is a place at an extreme end of the scale of existence. Freezing cold during winter, soils heaved by frost, swept by powerful winds and crushed by snow, plants and animals need special adaptations to survive here.

Ecosystem outline

WIDELY KNOWN as 'the alps', Victoria's high country is found along the axis of the Great Dividing Range into NSW and came into existence about 100–60 million years ago.[233] The mountain peaks are rounded, rather than jagged, because they are old and weathered, and did not have extensive glaciation.

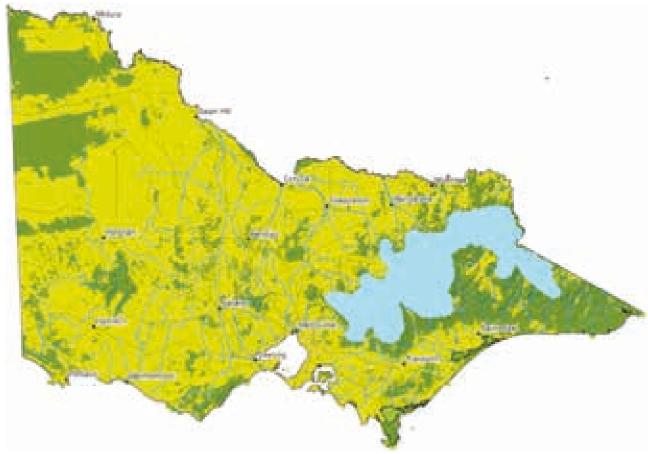
Unlike anywhere else in Australia, the alps usually receive seasonal snowfall. This difference is reflected in the plants and animals many of which are restricted (endemic) to these high mountain environments.

The high altitude, treeless zone is referred to as 'alpine'. In Australia, alpine areas cover less than 0.1% of the landscape.

Comparison of tree lines throughout the world, though they vary in altitude, show that they have one common factor – annual soil temperatures are less than 5.5°C (previously, the mean temperature of the warmest month being around 10 degrees Celsius was considered the limit.[234,235]). Thus, a lack of trees can be explained by the constant cold, a coldness that is sustained year-round and the dryness when water is locked away as snow and ice.[236] Extreme snowpack may also limit tree growth through preventing access to enough sunlight.

The tree line in Victoria's alpine areas has been very stable through time although there is recent evidence of Snow Gum (*Eucalyptus pauciflora*), the dominant tree species at high altitude, encroaching into grasslands at Mt Hotham.[237]

Disturbance by fire influences recruitment around the tree line. Studies in Victoria[238] and the Snowy Mountains in NSW[239] looked at Snow Gum seedling recruitment following bushfires. They compared seedling establishment above and below the tree line. In Victoria, saplings advanced into treeless areas over a 16-year period pre-fire but none were seen above the treeline in twice burnt areas. Thus, it appears that fire disturbance, probably with other factors, is playing a role in filtering out tree recruitment.



Approximate distribution of alpine vegetation in Victoria.

A survivor. This Snow Gum shows evidence of past fire (the multi-stemmed, mallee habit), of extreme wind and heavy snow (bending away and torn-off branches) and is in a desperate struggle to survive. The self-pruning of lower branches may be a response to drought. Nevertheless, it has grown to a huge size in a freezing location. © Karen Alexander.

Maisie Carr (*née* Fawcett; 1912–1988)

Maisey Carr at 32 years of age. She was an innovative botanist and ecologist. Her work helped us to understand alpine ecology. Public domain.

THE WORK of understanding alpine ecosystems began in the 1940s.

Since the 1820s, European settlers had taken cattle and sheep into the Victorian alpine areas for summer grazing. For a long time, this activity was effectively unregulated, despite licenses being issued.

Alpine areas have long been recognised as important sources of water in catchments. Around three quarters of the water in the Murray River comes from one percent of its catchment being the alpine area.

In 1941, concern about the effect of grazing on water run-off led the newly formed Soil Conservation Board to partner with J.S. Turner, Professor of Botany at the University of Melbourne, to investigate soil erosion and the ecology of the Bogong High Plains of Victoria. Turner appointed a new botany graduate, Stella Grace Maisie Fawcett (1912–1988, later Carr) to undertake this research.

Fenced exclosures established by Turner at Mt Mesley and then by Fawcett in Rocky Valley, near Falls Creek, were used to monitor the effects of cattle grazing. In January 1945, the Rocky Valley site was fenced off to exclude cattle. Maisie and her colleagues, who called themselves the 'High Plains Plant Hounds', monitored the sites until 1949. Turner and Fawcett concluded that summer livestock grazing was detrimental to native vegetation and published their study in 1959. It wasn't until 2015, at the second attempt, that grazing was finally banned from the Alpine National Park. The plots established by Maisie Fawcett continue to be monitored to this day making them one of the longest monitoring sites in Australia.[240,241,242]

Maisie Fawcett's legacy of fenced exclosures has helped us to understand alpine ecosystems. Maisie on a horse, Bogong High Plains, 1949. By an unknown photographer.[243]

Fenced plot (at left) established by Maisie Fawcett in 1945 on the Bogong High Plains. In 1989, it clearly shows the effect of cattle grazing in reducing plant biomass and diversity. © Stephen Platt.

If you look across alpine areas at Mt Buffalo in Victoria, you will notice trees at higher elevations than treeless areas. How could this be so? Isn't it colder the higher you go? The 'inverted treeline' is due to cold air drainage along the bottom of valleys. Cold air is heavier and sinks to the lowest parts of the landscape, with heavy frost preventing trees from growing there. Warmer temperatures at higher elevation allow trees to persist. Waterlogging of lower areas and exposure to strong winds can also influence the tree line.[244,245]

Snow is a defining feature of the alpine area and its ecology. Where it lies, snow acts like an insulating blanket. Beneath the snow, temperatures are more stable than in exposed areas which exhibit greater temperature fluctuations, more days below freezing and higher surface temperatures. At first it seems odd, but snow-covered areas are warmer than bare areas during winter.

Also of great influence is the effect of cold. It has significant consequences for all species primarily because it takes energy to stay warm and energy requires sunlight or high calorie food. Both of these are in short supply in alpine winters. Many plants shut down over winter and animals hibernate in order to conserve energy. Some animals avoid the cold by migrating to lower elevations. Survival in the alps requires a strategy for dealing with cold.

Mountains exist because of their geological history. They tend to have erosion-resistant rocks. In Victoria, granite, a hard, low-nutrient rock-type that is formed when volcanic lava fails to breach the surface and cools slowly, underlies several alpine areas (e.g., Mt Buffalo, Mt Baw Baw, Mt Wills).

Generally, alpine soils tend to be nutrient-poor, high in organic matter (due to slow rates of decay), acidic, friable and have a high, water-holding capacity.

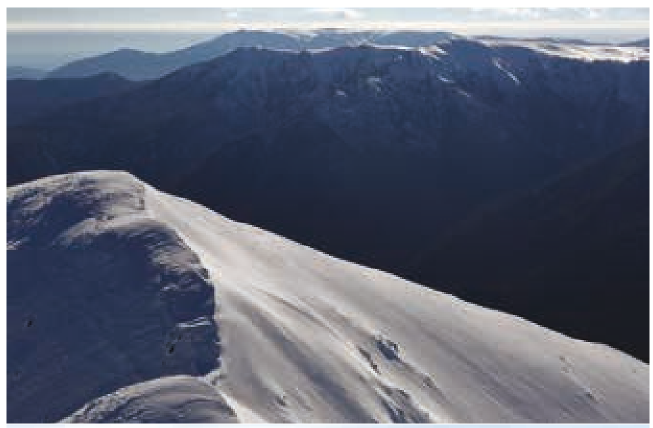
Cold, combined with low nutrient soils, means that plant growth in many alpine areas is sluggish.

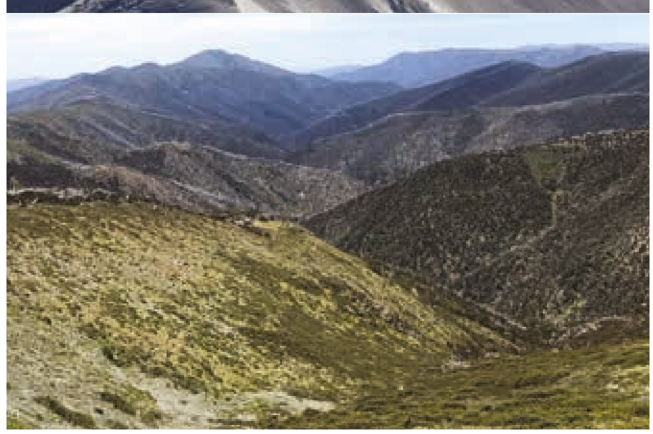
On steep slopes, flat terraces may form due to the slow downhill movement of waterlogged soil that freezes then thaws (solifluction terraces) – lifted up by ice, set down by gravity.

A lone Snow Gum in the 'treeless' alpine zone. © Stephen Platt.

Mt Buffalo landscape showing an inverted tree line and grasslands mixed with shrublands in the valleys. © Stephen Platt.

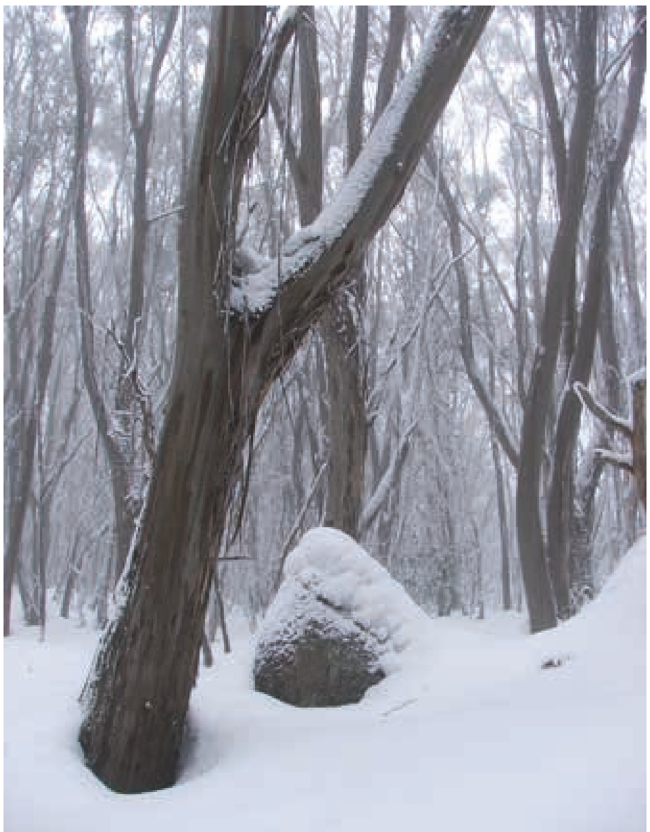
Above: Needle ice lifts soil and rock. Below: Frost prunes the growing tips of plants. © Stephen Platt.





Mt Feathertop, Bogong High Plains, is covered by snow in winter. © Ed Dunens. CC 2.0 Generic. **and sun-drenched in summer.** © Stephen Platt.

Late in summer, when the last of the snow melts, the snow banks turn pink. This is the snow algae *Chlamydomonas nivalis* blooming. It is characteristic of the Alps and appears in late lying snow patches such as above on Mt Feathertop. This single-celled organism must survive in the extremes of snow in winter and on rock and in soil during summer. © Stephen Platt.



Snow Gums at Lake Mountain. The depth and persistence of snow, temperature, altitude, exposure to wind and frost, and the depth and extent of moisture in soil influences plant communities across the alpine and sub-alpine landscape.[246] © Stephen Platt.

In order to understand alpine vegetation patterns, let us take a walk around the differing vegetation types and try to understand why they are there. Treeless areas support three broad vegetation types – tussock grasslands, heath-dominated shrublands and wetlands – and grade into treed areas at the margins.

1. **Poa tussock grassland. 2. Closed shrubby heathland. 3. Wetland. 4. Treed area.** © Stephen Platt, Mt Buffalo.

Firstly, if we stand in a *Poa* tussock grassland [Site 1 in image].

Here, less snow accumulates and it stays for less time. It is also windier, much colder, the soil is deeper and terrain flat. These conditions suit grasses and so *Poa* thrives here on gentle slopes and in hollows.[247,248,249,250]

Open shrubby heathland interspersed with grasses. Disturbance that opens up bare ground has enabled these shrubs to invade the grassland. © Stephen Platt.

Alpine Mint-bush (*Prostanthera cuneata*) is characteristic of closed heaths.

If left undisturbed for over fifty years Alpine Grevillea, and other shrubs (*Asterolasia* spp., *Phebalium* spp.), is replaced by *Poa* grasses. If disturbed, shrub seedlings regenerate in the gaps created by the disturbance.

Where the watertable reaches the surface, alpine bogs form.

Now let's move through the open heathland, which borders the tussock grassland, and into the closed shrubby heathland [Site 2 in image]. Closed heaths occur on wind-protected (leeward), steeper slopes where soils are shallow and rocky. These sites have least exposure to high winds and extreme frost. Open shrubby heaths occur at intermediate sites.

The boundary between the *Poa* grasslands and shrubby heaths is not static. What governs the boundary? Well, the shrubs are in competition with the grasses. Grasses compete by forming dense mats with their leaves. This prevents light reaching the soil level and prevents shrub seeds from germinating. That is the case unless there is a disturbance, such as a fire, that exposes bare ground. Then the shrub seeds can germinate and grow. They will rapidly emerge over the top of the grasses. If that happens, they will dominate the site for many years. As the shrubs age and die, if there is no further disturbance, grasses will re-occupy the site and the shrub seeds will once more find themselves covered by a thick mat of grasses and unable to get started. For example, if an undisturbed patch of Alpine Grevillea (*Grevillea australis*), which lives about 50 years, is not disturbed for over 50 years the patch returns to *Poa* grassland.[251,252,253.]

Animal activity, fire, frost and insect attack are other disturbances that create the bare ground that assists the shrub invasion.

Disturbances can be many years apart. Attacks by Swift and Case Moths on grasses, for example, occur once every 5–15 years. Fires in alpine areas of Victoria have historically occurred every 50–100 years.

If we continue our journey downslope, we encounter wetlands (alpine bogs) [site 3 in image]. Wetlands, with their unique flora, occur in valley bottoms where the water table reaches the surface or as spring-fed seepage areas on slopes. Peat soil forms in these areas as plant material accumulates, decaying very slowly due to the cold and lack of oxygen (anaerobic conditions). One metre depth of peat may take 1,000 years to form.[254] The depth of peat influences plant associations.[255] Though occupying a very small part of the landscape, the bogs of Australia's Snowy Mountains contain 49 million cubic metres of peat.[256]

The moss Sphagnum (*Sphagnum cristatum)* often grows prolifically at the wetland edge. Its growth is especially rapid where water flows. As the moss proliferates it can form a dam that creates a small pool. Gradual expansion of Sphagnum infills the pool which is subsequently colonised by shrubs and herbs. Over many generations, deep layers of peat, consisting of dead plant material, may develop.[257]

In the vicinity of wetlands, closed heaths occur on deeper peat soils and open heaths on shallower peats. Peat soils are characteristically high in carbon and acidic (low pH).[258] Herbfields containing Alpine Marsh-marigold *Psychrophyla introloba* and Alpine Tuft Rush (*Oreobolus pumilio* subsp*. pumilio)*, occur on stony pavements. Snow melt and runoff may dislodge fragments of these bog plants which then recolonise new areas.[259]

Finally, if we move into the trees [Site 4 in image] we find that shrubs dominate the understorey (see page 120 for discussion of the reasons for the tree line). In the shadow of the trees, snow persists longer and acts as a warming blanket preventing damage by colder frosts. This favours shrubs.

The reasons for these dramatic changes in vegetation type were first explained by Dick Williams in the mid-1980s.[260]

Infrequent, extensive fires are a feature of alpine ecosystems in Australia.[261] Based on tree ring evidence, they have historically occurred every 50–100 years[262] and typically follow extended drought.[263]

Most plant species are adapted to regenerate rapidly after fire, even high severity fires.[264] You can see evidence of repeated, non-lethal fire on some snow gums. This ecosystem is very resilient to infrequent, large, intense fires.

An alpine bog and Sphagnum (light green) at the edge of a pool. © Arn Tolsma.

Alpine Tuft Rush is colonising a stony pavement.
© Smilelynaomi CC BY-NC 4.0 (Int).

Patches of unburnt forest remain even when severe fires occur. © Stephen Platt.

This Snow Gum shows multiple fire scars, indicating survival after numerous, presumably low intensity, alpine bushfires. Cobberas. © Lucas Bluff.

Though usually protected by its water-holding capacity, in extremely dry conditions peat will burn. Fire is particularly destructive of peat soils. © David Cheal.

Recent and frequently burnt Snow Gum woodland can lead to a vegetation structure of many small stems – the result of post-fire coppice. © Stephen Platt.

This low intensity bushfire burnt Sphagnum hummocks but skipped the wetter spaces between them. Omeo Plain. © Nick Clemann.

Some Snow Gum specimens have the multi-stemmed habit of the mallee eucalypts, their trunks radiating from a large woody lignotuber. As in the Mallee, fire has killed the above-ground parts of the tree and it has resprouted from buds protected beneath the soil surface. The root systems of very large individuals may thus be hundreds of years old, as they survive fire events. Repeated fires can dramatically change stand structure toward many small stems.[265]

Tree girth has been found to be a reasonably reliable estimator of high-altitude Snow Gum age. A 100cm girth is approximately a 66 year old tree, 50cm: 43 years and 25cm: 27 years.[266]

In alpine areas, pollination is largely performed by invertebrates; the grasses, however, are wind-pollinated.

Shining Coprosma (*Coprosma nitida*) berries attract birds and mammals. © Tayloab. CC-BY-NC 4.0 (Int).

Long unburnt, this ancient snow gum may be thousands of years old. It occupies a site rarely subject to fire and has grown to a huge size despite the cold and nutrient poor soil. Its coppiced shape indicates survival after one or more intense fires initiated regrowth from its lignotuber. Large limbs indicate that the fire was long ago. So unique are such trees they should be regarded as national treasures. Note that one dead limb has been chain-sawed for firewood. © Stephen Platt

Given the low numbers of vertebrate animals in these environments, these are appropriate strategies for most species. However, the bright red berries of some plants (e.g., *Coprosma* spp.) are designed to attract birds, reptiles and small mammals, which disperse their seeds widely.

Overall, alpine plants have fairly poor long-distance seed dispersal.[267] Three quarters of all species disperse less than 10m and less than 20% more than 100m. The seeds of alpine plants, particularly species with larger seed mass at higher elevation, are relatively short-lived in comparison to other ecosystems.[268]

Grazing can have significant effects on alpine vegetation. The short growing season and fragile soils are easily damaged by grazing animals. Snow cover provides a limited protective effect during winter. Livestock grazing has been shown to affect plants through selective grazing of palatable herbs, physical damage to soils and vegetation and changed processes including increased weed invasion[269] and for these reasons has been prohibited.

Alpine plants have good and bad years of flowering. This is called 'mast' flowering – and it's the plant's attempt to avoid all the seed being eaten. In many years, almost all daisies and peas, such as *Hovea* spp., have their seeds eaten by the larvae of insects that lay their eggs in seed heads as a ready-made food source. Mass flowering overwhelms the insect population allowing some seeds to avoid being eaten. As a result, in some years the wildflower display is spectacular, in others less so.

Plant life

HOW DID unique alpine plants get to their mountain peaks? Did species undertake long-distance dispersal (e.g., hitching a ride with a bird); migrate along mountain chains, evolve from ancestors at lower altitudes or were they assisted by past glaciations?[270] Comparison of alpine floras worldwide shows that each association of alpine plants is more closely related than the surrounding regional flora.[271] This clustering is more prominent on tropical than temperate mountaintops. It appears that a few plant families evolved to tolerate cold temperatures, that they colonised alpine areas between glacial periods and that they remain genetic conservatives in their unique habitat. In other words, some of the local plants adapted, colonised the mountaintops and remain in their isolated realm.

Snow creates problems for survival of trees including branch-snapping weight, slow growth rates and cell death due to freezing. © Stephen Platt.

Mass flowering of Slender Snow Daisy (*Celmisia* sp. probably *C. pugioniformis*) which is widespread in the Victorian Alps and has a disjunct population in the Grampians. © John Morgan.

Snow Gums (*Eucalyptus pauciflora*) occupy most of Victoria's high mountaintops. Their branches are flexible, bowing under the weight of snow welded onto their thick, waxy leaves. The wax helps Snow Gum to cope with frost and may also reduce insect damage.[272]

Snow Gums in summer at Mt Buffalo. © Stephen Platt.

The compact, rock-hugging form of Carpet Heath (*Pentachondra pumila)* helps to keep it warm and avoid physical damage from the weight of snow. Red berries attract animal seed-dispersers. © Russell Best. CC-BY-NC 4.0 (Int).

Alpine Marsh Marigold (*Psychrophila introloba*) wastes no time, making the most of the short summer season by flowering on the edge of snow melt.
© Friends of Chiltern Mt Pilot, CC BY-NC-SA 2.0.

Most alpine plants tend to be dwarfed due to seasonal snow, low temperatures, low nutrients, limited seasonal growth opportunities and high winds. The tussock and rosette form of many plants effectively traps heat such that leaf bases can be 5^{0}C higher than ambient air temperature.[273] Many plants have a growing point close to the soil surface. This helps to protect them from frost and is an adaptation to grazing and fire.

Over winter, many plants store energy as carbohydrate in underground tubers or stems. Some species, such as *Phebalium* spp., develop their flower buds in autumn. This preparation allows rapid growth and reproduction as soon as the snow melts. Following their winter dormancy plants must grow rapidly, after snowmelt, flower and set seed before the following winter.

The balance between energy stored during summer and energy lost during the rest of the year is a fine one. Some plants take a conservative approach and grow extremely slowly. For example, Mountain Plum Pine (*Podocarpus lawrencei*) stem diameter grows 0.25mm per year (see page 130).

Compared to lowland ecosystems, peak wildflower displays are delayed due to the cold. They occur in December-February, which is the alpine 'spring'. Alpine Marsh-marigolds (*Psychrophyla introloba)* make the most of the time available by flowering at the edge of snow melt or even under snow. Mountain Gentian (*Gentianella diemensis*), Waxy Bluebell (*Wahlenbergia ceracea*) and Grass Trigger Plant (*Stylidium graminifolium*) flower later in the season, in February – March. Thus, there is a continuous supply of flowers to support invertebrates throughout the snow-free period.[274]

Sites with the most exposure to sun typically support plants with fine needle-like leaves. This enables them to dissipate heat more efficiently than if they had broad leaves.

Waxy Bluebell *(Wahlenbergia ceracea)* is one of many herbs that grow between grass tussocks (Bennison High Plains).
© Stephen Platt.

Alpine plants must cope with late-season snowfalls.
© Stephen Platt.

Alpine wildflowers

1. Snow Daisy *Celmisia* sp., 2. Spoon Daisy *Brachyscome spathulata*, 3. Spotted Sun Orchid *Thelymitra ixioides*, 4. Royal Grevillea *Grevillea victoriae*, 5. *Podolepis robusta*. © Stephen Platt.

Mountain Plum Pine near the rocky summit of Mt Cobbler where it has escaped fire. © Stephen Platt.

High up in the shelter of rocks, on cliff-faces or sprawling over boulder streams, it is possible to find the Mountain Plum Pine (*Podocarpus lawrencei*).[275] Despite its usually low height – there is an exceptional population at Goonmirk Rocks that grows to 20m tall – and spreading form, these plants can live up to 600 years of age. Plum Pines are found among the rocks because they act as a refuge from fire, which kills this species of conifer. Rocky habitats also provide maximum light and warmth during the snow-free, growing season.

Attracted to towers of mauve blooms, a small insect heads toward a Trigger Plant (*Stylidium* spp.). It is being coerced into carrying the plant's pollen but it is unaware of its role. It lands on a flower. As it probes into the throat of the flower for nectar, hairs trigger the bent-back 'hammer' to release and suddenly the insect gets a thumping surprise. The arm flies forward like a hammer to an anvil. The tip of the hammer carries packets of pollen which are stamped onto the insect. It survives the encounter and flies off to another flower. In older flowers the pollen sacs have matured and are pushed aside by the handle of the hammer which, instead of depositing pollen, collects it from the visiting insect and is pollinated. After a period of time, about 10–30 minutes, the trigger resets ready for the next naïve insect. You can view this mechanism in action by inserting a sharp object into the flower centre, mimicking the action of the insect seeking nectar. It works much faster in warm weather. Trigger Plants are common throughout Victoria and a conspicuous feature of alpine environments.

Male cones on Mountain Plum Pine, Mt Cobbler.
© Stephen Platt.

Red, berry-like cones of a female Mountain Plum Pine. These are eaten by birds and marsupials but are toxic to other mammals, including humans.
© M. Fagg, Australian National Botanic Gardens. www.anbg.gov.au/photo.

Trigger plants have a surprise waiting for their insect visitors.
© Stephen Platt.

Trigger Plant (*Stylidium graminifolium*), 'hammers' at the ready, will react if probed with a very fine stick.
© Lorraine Phelan. CC-BY-NC 4.0 (Int).

Immediately below the alpine zone, sub-alpine tall wet forests grow in sheltered sites. Ferns and broad-leaved shrubs proliferate under Alpine Ash (*Eucalyptus delegatensis*) at this wet site on Mt Stirling. © Stephen Platt.

When snow falls below the tree line, tree ferns relax their fronds to allow it to fall off without breakage. Lake Mountain.
© Stephen Platt.

Animal life

THE ALPINE regions do not support a rich vertebrate fauna. It's just too cold for most species. Of the native mammals, Bush Rat (*Rattus fuscipes)*, Common Wombat *(Vombatus ursinus)* and Agile Antechinus *(Antechinus agilis)* are the most common residents.[276] The diminutive Mountain Pygmy Possum (*Burramys parvus*) is the most specialised alpine inhabitant. Birds tend to be those that are capable of moving away when the conditions deteriorate, particularly over winter (e.g., Flame Robin). Reptiles are represented by some skinks and there are a few specialist frogs, notably the Alpine Tree Frog and Baw Baw Frog.

The space beneath the snow is called 'subnivean' and many animals remain active here during winter.

Several hundred million years ago glaciers covered most of the high mountains in Victoria. The glaciers insulated the ground beneath them but around their edges annual freezing and thawing shattered exposed peaks and ripped off large boulders. Lifted up and dumped by ice over and over again, on sloping ground the boulders slowly slid downhill across the frozen subsoil. Subsequently, the soils between the boulders washed away to leave behind a legacy of 'boulder streams'.[277] These unique environments are home to the Mountain Pygmy Possum and Mountain Plum Pine. The Pine is here because it is very sensitive to fire and the rocks provide refuge from it. For the tiny possum, the rocks provide refuge from predators and food in the form of pine seeds.

Mountain Pygmy Possums were thought to be extinct until 1966 when a live animal turned up in a ski lodge at Mt Hotham.

Few species are more specialised than the Mountain Pygmy Possum. It lives as small populations in boulder streams and relies on an abundance of migrating moths to eat in summer.

Female possums give birth to three to four young in spring and, after a few weeks in the pouch, leave them in a nest shared with other mothers deep in a boulder crevice. After mating, males are driven away and spend most of their lives on the fringes of the best habitat. Females live together in groups of up to ten related individuals.

Mountain Pygmy Possums spend the winter months in hibernation. As the snows melt, they emerge to feast on Bogong Moths, a critical component of their diet. The moths migrate to the mountains during spring after a long journey of up to 965 km from where their grubs developed in the lowland pastures of New South Wales. After hatching, their larvae feed on the roots of pasture plants during autumn and winter. In spring, adults emerge and fly to the alps. This long-distance migration to the cool mountains is for a period of summer dormancy (to aestivate). They do not breed here but do congregate in rock crevices, caves and other places with stable environments. Such a costly migration is most likely due to their need to avoid the heat and lack of water during summer on the plains. At the end of summer, they return to the far away pastures to breed and lay eggs.[278] When the moths return to the lowlands to breed, Pygmy Possums switch to fruits and seeds, including the succulent bright red 'berries' of Mountain Plum Pine.

Mountain Pygmy Possum – an alpine specialist. © Glen Johnson.

Fire is a threat to Mountain Pygmy Possums, particularly in the time of climate change. See if you can spot the possum in this image. Source: DELWP. CC 3.0 (Aust.).

A boulder stream surrounded by Mountain Plum Pine at Mt Little Higginbotham. © Stephen Platt.

Agile Antechinus. © Brett Vercoe. CC-BY-NC 4.0 (Int).

Bogong Moths congregate in rock crevices in the alps. © CSIRO CC 3.0

Agile Antechinus give birth to many undeveloped young that mature in the 'marsupium' or pouch. © Sue Tardif. CC-BY-NC 4.0 (Int).

Bogong Moths were an important food source for Aboriginal people. Moths were collected from rock crevices using sticks and, if not eaten immediately, were roasted to remove their scales and wings, then made into a paste and formed into long-lasting flat cakes. Aboriginal excursions to the mountains for Bogong Moths had an important social function, bringing disparate mobs together.

Flame Robins breed in the upland forests and descend to lower elevations during autumn and winter. This vertical migration allows them to avoid the cold of winter. Their nest is built of grass and bark bound together with spider's web and camouflaged with lichen. The nest is usually placed in a cavity in a tree or rock face (see images page 63).

Some small mammals, such as the Agile Antechinus and Bush Rat, remain active over winter. They use tunnels under the snow. As in all antechinus species, there is a short breeding season after which all the males die. Agile Antechinus' live in family groups of up to 20 individuals and feed on invertebrates, small lizards and berries.

The Pied Currawong (*Strepera graculina*) is a large, mostly black bird with a yellow eye, that hunts for young birds and also eats small lizards, insects, caterpillars and berries. I have observed them attacking an Eastern Ring-tailed Possum in its drey during the day. On another occasion they chased a Sugar Glider mid-air after it was forced to take a life-saving leap to a safer hollow. Walking in these environments you often see pellets of the berry seeds Currawongs regurgitate. Named after its call, the echoes of 'curra-wong' fill the mountain slopes, especially in the late afternoon.

Flame Robins are altitudinal migrants. © Stephen Platt.

The endangered Guthega Skink (*Liopholis guthega*) occupies open grasslands, shrublands and woodlands of the Bogong High Plains – the only area in which it occurs. It lives in burrows under rocks as family groups. Females give birth to live young. Adults live around 8–10 years. They eat invertebrates throughout most of the year but switch to berries, such as those of Snow Beard Heath (*Acrothamnus montanus*), in late summer.[279]

The haunting calls of Pied Currawong can be heard throughout the high mountains. © Lip Kee Yap CC 2.0

Guthega Skink. © dhfischer CC BY-NC 4.0

Currawong pellet. © Stephen Platt.

Gang Gang Cockatoos (*Callocephalon fimbriatum*) are also altitudinal migrants. Summer is spent in the tall, shrubby mountain forests of the high country and winter at lower elevations in open forests and woodlands. In the non-breeding season, groups of up to 60 birds may form. Pairs or small family groups are typical of the breeding season. They primarily eat seeds but will also feed on berries, fruits, nuts and insects. Gang Gangs form strong monogamous pairs. Eggs are laid in a tree hollow and both parents co-operate on all duties. Where breeding sites are close by, a creche of young birds may be formed giving some parents the ability to feed whilst their young are minded.

Forest-dwelling Gang-gangs can be thought of as 'bush Galahs'[280] Galahs thrive in the open woodlands at low elevations. They can process their food of seeds using their bill and tongue alone. In contrast, Gang-gangs, like other black-cockatoos, must use their bill in combination with their foot to handle food. The shape of their bill differs from Galahs, hence the different eating methods. This feeding technique is better suited to, and why they are found in, forest habitats.

Alpine Tree Frogs (*Litoria verreauxii alpine*} were once so abundant that buckets full were collected for university pracs. Now they are vulnerable to extinction probably as a result of increased exposure to UV radiation, disease


Male Gang Gang Cockatoo. © Juliet Lowther.


Alpine Tree Frog. © Nick Clemann.


Baw Baw Frog. © Zoos Victoria.

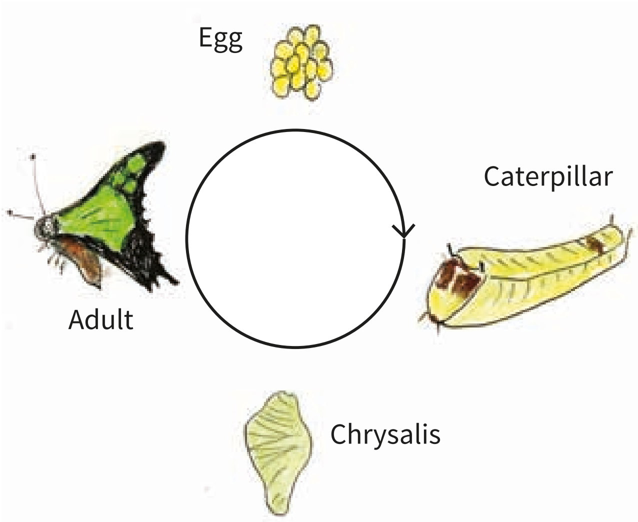
(chytrid fungus) and destruction of their wetland habitats (e.g., by feral horses). A subspecies of the more common Whistling Tree Frog, they are found in a range of habitats including alpine grasslands and herbfields near water. Males call from the edge of pools and eggs are attached to submerged vegetation. Tadpoles emerge as young frogs in late summer. They eat invertebrates including beetles, flies, spiders and moth larvae.

The endangered Baw Baw Frog (*Philoria frosti*) exists only on the Baw Baw Plateau of Victoria. It lives close to seepage lines coming from sub-alpine wet heath and in mountain gullies. Breeding habitat is in natural cavities – 'love caves' – under vegetation, logs, peat, soil or rocks. Males call during the day and night. Up to 185 eggs are laid in a transparent foam mass close to the cavity which may be near the surface or up to a metre deep. The female creates the foam by beating her forearms to push air bubbles into egg gel. After five to eight weeks the tadpoles hatch. They will not feed until they become a frog as they can live off a large yolk sack provided by their mother. The adult frogs feed on invertebrates with a preference for earthworms. During the non-breeding period, they live anything up to 80m from their breeding site.[281]

MacLeay's Swallowtail (*Graphium macleayanus*) has a typical butterfly life cycle. Eggs are laid on specific food plants that sustain the caterpillars after hatching. The caterpillar forms a cocoon (pupates) and then lives a brief life as an adult butterfly.

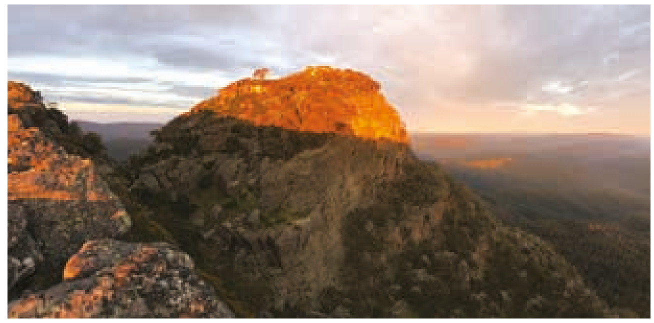

MacLeay's Swallowtail on Mt Buffalo. © Stephen Platt.

Typical butterfly life cycle



As in all butterflies, it has an extrudable, soft, fleshy, orange-coloured organ behind the head that emits foul-smelling odours as a defence against predators and parasites. But how does a small forest-dwelling butterfly find a mate? Sometimes on hot mornings they can be found 'hill-topping' on a prominent mountain peak or ridgeline. Heading to a hilltop is a way for low density species to find one another and look for a potential mate.[282]

Plague Soldier Beetles (*Chauliognathus lugubris*) gather in huge swarms to mate. Their larvae live in the soil and feed on soft-bodied invertebrates. Adults feed on pollen and nectar. They are named after the coats worn by soldiers. © Stephen Platt.



Mt Cobbler is a prominent isolated peak that appears to attract mating butterflies. © Stephen Platt.

Alpine Stoneflies are confined to a small area of alpine Victoria. © Dianne Crowther.

An endangered female Alpine Stonefly (*Thaumatoperla alpine*) lays a mass of eggs into a fast-flowing, shallow, cold, alpine stream. The eggs will gradually break apart and, after several months, nymphs will hatch. They will live in the stream for three years, sheltering under stones or plant debris, eating plant material and preying on animals. After several growth stages, the nymph will emerge from the stream as an adult. It will live for just two months whilst feeding on lichen, plant tissue, diatoms and perhaps instream phytofall. They are poor flyers and do not venture far from the stream. Alpine Stoneflies spend the night at the base of plants, presumably to keep warm. This species is found no-where else but on the Bogong High Plains.[283]

Alpine ecology is driven largely by temperature. Plants and animals have adaptations that allow them to persist in this inhospitable environment. Given the significance of cold to their ecology, in the era of a warming climate, alpine ecosystems are perhaps one of the most vulnerable in Australia.

Cover image: we can see the skeletal nature of the soil among conglomerate rock; the short-statured, compact everlasting that can cope with snow-cover and, in the distance, the dead grey spars from a previous fire.
© Stephen Platt.

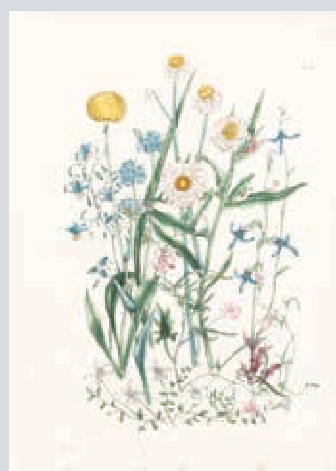
Where to see this ecosystem

- Alpine National Park
- Mt Baw Baw National Park
- Mt Buffalo National Park
- Bogong High Plains
- Dargo and Davies Plains
- Lake Mountain

Baron Sir Ferdinand von Mueller (1825–1896)

Baron von Mueller in Melbourne.
Source: National Library of Norway. Public Domain.

BARON SIR Ferdinand von Mueller, first government botanist in Victoria, was an adventurous young man who travelled to Australia from Europe when it took five and a half months by sailing ship, who repeatedly wandered solo through the Victorian bushland collecting plants and who accompanied A.C. Gregory's expedition across northern Australia. His apprenticeship, at 15 years of age in Germany, as a pharmacist involved understanding the medicinal qualities of plants and this led on to his lifelong interest in botany. He was a tenacious scientist leading the early taxonomic work to describe the flora of Australia. He was a foundation member of the Royal Society of Victoria and Director of the botanic gardens, herbarium and attached zoological park. He was also something of an oddity. Happiest alone, unfashionably dressed, he struggled socially. His early life experience of losing both parents and a sister to tuberculosis influenced his thinking and actions. Though awarded many honours by Europeans and encouraged to return to Europe, he never did so. Mueller was a prolific writer. He wrote over 2,000 letters a year to peers and collectors. This added up to tens of thousands of letters across his career as well as 1,000 scientific papers and 40 books. He lived as a bachelor with almost a horror of intimacy. At the age of 36 he was briefly engaged to an older woman named Euphemia Ethel Elizabeth Spencer Middleton Henderson.[284] He escaped the forthcoming marriage by claiming his health made it impossible for him to consummate it. That is, he claimed to be impotent! Mueller was eventually usurped as Director of the gardens by Guilfoyle, sacked by public demand, and died following a stroke on 10 October 1896.



At the age of 29, in 1857, Fanny Anne Charsley arrived in Melbourne from England. Soon after, she contacted Ferdinand von Mueller and volunteered as a plant collector. Trained as a watercolourist, she illustrated her collections accurately and, in 1867, published them in 'The wild flowers around Melbourne'.
Source: State Library of Victoria.

Getting to know our fungi, lichens and mosses

Often overlooked, fungi, mosses and lichens are extremely important components of ecosystems and often fundamental to ecosystem health. Whilst identification of some species can present a challenge, others may be very distinctive. © Stephen Platt

Getting to know fungi, lichens and mosses

SOMETIMES CALLED *cryptogams* (meaning to reproduce by spores and not seeds), these organisms lack the tissues for transporting fluids around their body (are non-vascular). If we lacked blood vessels, we would need to be small so that oxygen, food and waste could be dealt with through diffusion, and so it is for cryptogams, lacking the necessary vessels, they are confined to being small in stature but not in importance.

Fungi are so different from other organisms that they are classified into a separate kingdom. They do not need to photosynthesize (are heterotrophic) and do not have chlorophyll like plants. Instead, they rob the energy gathered by other species. Fungi produce spores and have unique cell walls. There are around 11,846 described species in Australia of which one third are lichens.[285, 286] The diversity of fungi in sclerophyll forests could be as high as 1000+ species per hectare. Twenty-five species of one genus were found within a 100ha area. It was estimated that they produced 181,000 fruiting bodies per hectare per month.[287]

Fungi are most readily detected via their fruits ('mushrooms'), though some species fruit underground.

Mosses grow in most environments and generally require moisture although some species can dry out completely and, following rainfall, resurrect themselves in a very short time (12–24 hours). Mosses are capable of sexual or asexual reproduction. They are often a significant component of the vegetation in wet sites and particularly in wet forests. After fire, in the absence of vascular plant canopy cover, they may dominate the ground layer for a short time.

Lichens are a symbiotic relationship between an alga and a fungus. There are 3,500 species of lichenised fungi in Australia.[288] They occur in all habitats. Lichens are more than the sum of the partners. They produce over 800 substances in partnership that the fungus and alga alone do not. Lichens occur in some of the most adverse conditions for living things, growing on solid rock and across barren soil.

Liverworts – many species look like flattened moss. They share a similar reproductive system to mosses and hornworts.

Ecological roles

Cryptogams are extremely important in all ecosystems. They form mutually-beneficial relationships with plants (symbiotic), help to rot plant and animal remains (decomposers), recycle nutrients, contribute to the formation and stabilization of soils and are food for animals.[289] Their symbiosis with other plants (as mycorrhizae) is essential to maintaining plant health and is thus fundamental to every ecosystem.

Dawsonia superba **is the tallest (up to 60cm) self-supporting moss in the world and found close to Melbourne.**
© Reiner Richter. CC-BY 4.0 (Int).

Post-fire liverworts. © Stephen Platt.

The Ghoul Fungus (*Hebeloma aminophyllum*) is found in soil enriched by the corpses of animals including kangaroos and lizards. It also fruits in nitrogen-enriched, urine-soaked soil.
© Paul George. CC-BY-SA 4.0 (Int).

1. Mosses cloak the sandy ground at Wilson's Promontory National Park after the Black Saturday bushfires 2009. 2. Lichens cover this branch. 3.Rainbow Fungus (*Trametes versicolor*). 4. A jelly fungus. © Stephen Platt.

The native Honey Fungus (*Armillaria luteobubalina)* is found at the base of living and dead trees. A parasite, it attacks and invariably kills shrub and tree species.
© Torbjorn von Strokirch CC-BY-NC 4.0 (Int).

Morel Fungus (*Morchella* sp.) respond to fire (are pyrophilous).
© Gordon Friend.

A soil encrusting lichen. © Stephen Platt.

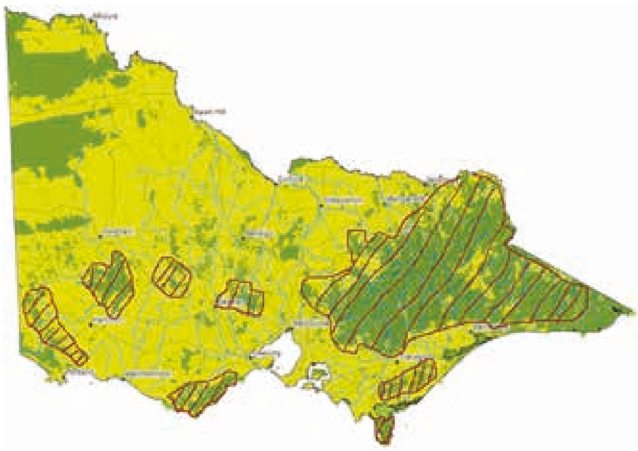
***Cortinarius archeri* is mycorrhizal and associates with *Eucalyptus* roots.** © Stephen Platt.

Foothill Forests – the gentle mosaic

In this image of foothill forest, mixed eucalypt species (as shown by the different bark types) tower above a shrubby understorey. Small-leaved shrubs are located in the foreground but broad-leaved shrubs dominate the background slope. Why is there so much diversity of life form? © Stephen Platt.

Foothill forests – the gentle mosaic

***A SCENTED** trap, a nest parasite that eats hairy caterpillars, our most unfaithful bird, a plant that's been used for bedding and once brought down the brick industry, a murder mystery that's been solved, mate till you and all the competition die, leaving a poo cairn where others will see or smell it, given away by the distinctive odour of a communal latrine, truffles for dinner please, a damsel who undresses above water and an animal that eats magpies. Our extensive foothill forests are full of curiosities.*



Approximate distribution of remaining foothill forests in Victoria.

In this cutting you can see the layers of sediment, tilting up to the right, that were once deposited on the bottom of an ocean. Old, nutrient poor, formerly marine, sedimentary soils are widespread in the foothill forests of eastern Victoria.

Introduction

THESE ARE the forests in which we often picnic, bushwalk and camp. They occur on a folded landscape of hills and valleys, primarily of the Great Dividing Range. Slope, aspect and water availability, and their influence on fire, create a forest mosaic that affects vegetation and wildlife. These forests are 'gentle' in the sense that they occur where there is moderate rainfall at elevations below the snowline, away from the influence of the sea and inland deserts. The climate is moderate and supports medium to tall trees.

Ecosystem outline

THE FOLDED landscape, creating slopes facing or away from the sun, and providing or denying access to moisture, creates the environments for life in the foothills. It is like a giant, contorted jigsaw in which some pieces are dry, some wet, some on steep shallow soils, others on flat deep alluvial soils and yet others that burn more frequently or intensely. Fire, which is a regular disturbance in these forests, is influenced by topography. Dry slopes burn more often but less intensely than wetter slopes with more broad-leaved shrubs. Steep, windward slopes burn more quickly than flat or leeward slopes.

The foothill forests of Victoria typically consist of a mixture of eucalypt species – peppermints (Narrow-leaf Peppermint [*Eucalyptus radiata*] and Broad-leaf Peppermint [*Eucalyptus dives*] are widespread), stringybarks and gums – that intermingle along the slopes of the Great Dividing Range which follows the east coast of Australia.

The diversity of eucalypts and other plants is influenced by the convoluted nature of the landscape. Each combination of aspect, slope, soil fertility and water availability advantages one species over another and sets up a pattern that may appear, when viewed in the distance, as a palette of varying, repetitive greens, each one reflecting a different cohort of species.

Rivers and streams follow the valleys in this landscape. They provide unique, linear environments, subject to the influence of what happens in the catchment such as ash from a fire, erosion leading to sedimentation or lack of water input due to drought.

Soils in parts of the foothill forests are ancient, dating from the Cambrian period (541 million years ago), when an explosion of multi-celled organisms, including trilobites, occupied the oceans, to the mid-Devonian (387 My bp), the age of fishes and vascular plants. They consist of mudstones, shales and sandstone rocks indicating their marine origin. Whilst originally being formed on the bottom of the sea, they were pushed up when Australia collided with the tectonic plate containing New Zealand and South America around 300 million years ago.[290]

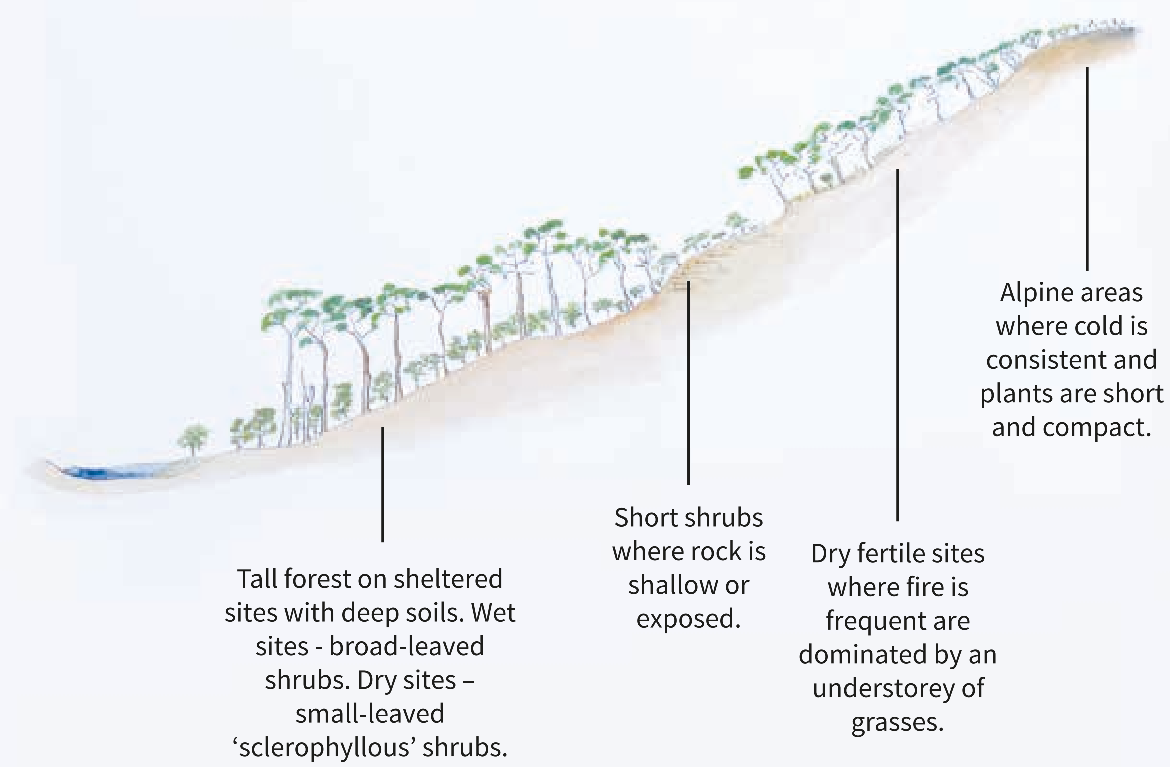
Can you see the mosaic of lightly forested and densely forested slopes in this aerial view of foothill forests surrounding the Murray River at Murray Gates in north-eastern Victoria? The pattern of vegetation relates to aspect, slope, water availability, soil depth, fire history and other influences.
© Stephen Platt.

The Snowy River provides a habitat for many aquatic species, and a source of water and food for terrestrial species.
© Stephen Platt.

Beneath the trees, the understorey also varies with site characteristics. On dry, fertile slopes, it may be open and grassy; or on dry, less fertile slopes consist of small-leaved shrubs; or near watercourses and on shaded slopes be dense with broad-leaved shrubs.

These forests are sometimes referred to as 'Dry Sclerophyll' and 'Wet Sclerophyll' (sclero-phyll meaning hard-leaved). On dry sites, many of the shrubs do, in fact, have small, hard leaves as a way of dealing with water conservation and animal browsing.

The effect of altitude on plant distribution and form in foothill forests



The small-leaved (Dry Sclerophyll) foliage and spines of Gorse Bitter Pea (*Daviesia ulicifolia*) help to prevent water loss and provide some protection from browsing animals.
© Stephen Platt.

Blanket Leaf. Reiner Richter. CC-BY 4.0 (Int).

On shaded, wet slopes, broad-leaved shrubs, such as Blanket Leaf, may dominate the understorey. © Stephen Platt.

'Wet Sclerophyll' forest consists of tall eucalypts over broad-leaved shrubs, such as Blanket Leaf (*Bedfordia arborescens*) and Hazel Pomaderris (*Pomaderris aspera*), ferns, herbs and coarse grasses.

Phytofall (mean of 233g/m^2 per annum) accumulates primarily in late summer and is mainly composed of leaves (78%).[291] It represents nearly one fifth (17%) of total, above-ground biomass (980g/m^2 equiv. to 4.2 years accumulation of phytofall) and decays in about 3.5 years.[292] Phytofall provides habitat for a wide range of invertebrates, fungi and other organisms. They obtain food through decomposing this material and so sustain the 'decomposer' food chain (c.f. the food chain of photosynthesis, herbivores and carnivores). Decomposer activity reduces the total above ground biomass. The action of decomposers also affects the fire regime. As fine organic material accumulates after a fire, so too does the risk of fire. By removing fine organic material, organisms reduce the fire risk, not to zero but to less than it otherwise might have been. Thus, phytofall is a key component of the ecology of the foothills. It sustains the decomposers; they influence fire intensity and fire regimes influence the type of forest at a site.

As a component of phytofall, logs play an important role in foothill forests. Animals use them as shelter and nesting sites, places to hunt for food, basking and hibernation sites, runways that assist movement and as perches. Plants use logs as germination sites. Fungi grow through logs and fruit on them. Logs protect wet places from the sun and, especially during drought, retain moisture that sustains organisms. When they decay, logs add to soil nutrients that support forest health. Unlike fine leaf and twig material (fine fuels), logs do not contribute significantly to the rapid passage or immediate intensity of a bushfire though they may keep burning long after the main fire front passes.

Agile Antechinus traversing a large log at night.
© Graeme Lunt. CC-BY 4.0 (Int).

Stringers of bark hang from branches and bark surrounds the base of gum-barked eucalypts. © Stephen Platt.

The Huntsman Spider's (*Isopeda montana*) body shape allows it to shelter and hunt under loose bark. They are fast-moving predators of small invertebrates. Their lifespan is around two years. © Paul2George. CC BY-SA 4.0 (Int).

A patchy fire in which some tree crowns have burnt, others are scorched and some areas of canopy remain as unburnt vegetation. © Lucas Bluff, DELWP. CC 3.0 (Aust.).

Detached bark on trees provides the cracks and crevices (sub-cortical space) that hide many small 'hollow' users including bats and invertebrates. The flattened body of a huntsman spider is ideally suited to these spaces.

Due to the moderate rainfall and seasonal climate, fire is fairly frequent in this ecosystem, with severe fires occurring every 15 to 45 years. Fire at a particular location may vary from this frequency. Frequent burning, especially on dry north and west-facing slopes, tends to encourage a simple ground layer of grasses (on higher fertility soils) or ferns such as Austral Bracken or coral-fern (*Gleichenia* spp.) on low fertility sites.[293] Ferns and grasses are resprouters and grow rapidly from rootstocks after fire. A greater time between fires, and cooler, wetter aspect, will favour shrubs some of which resprout after fire whilst others do not.

After fire, different-coloured epicormic shoots betray the different species of eucalypts present at this site north of Walhalla, 2009. © Stephen Platt.

Fire is a significant risk to large, old trees and the unique resources, including hollows, they provide to wildlife. Left: Standing tree prior to fire. Right: the scar left behind after it has fallen and been completely consumed by fire. © Stephen Platt.

A profusion of wildflowers (e.g., White *Pimelia* sp., mauve *Tetratheca* sp., and orange *Daviesia* sp.) often follows fire. © Stephen Platt.

Large, old, hollow-bearing trees are important habitat for Powerful Owls, Common Brush-tailed Possums and other large animals in these forests. They take a long time to develop, are generally few in number and are important habitat for many species of wildlife.[294]

Spotted Pardalote at the entrance to a hollow in a large, old River Red Gum. © Juliet Lowther.

Tree hollows are used for shelter and breeding, perching and denning, and protection from predators. Only large, very old trees provide hollows of the size needed by larger animals such as owls, cockatoos and kookaburras. The entrance diameter, depth, insulation qualities, height in the tree, landscape position and other factors contribute to whether a hollow will be occupied by particular wildlife species. For example, a hollow facing the sun may be too hot to occupy in summer. Hollows can be a defence against predators, but also a potential trap if the predator can access them. Thus, animals will usually select an entrance size just big enough for themselves to fit through but too small for their predators.

A Striated Pardalote attending its nest hollow. © Stephen Platt.

Eucalypts may take in excess of 120 years to develop small hollows and many more before large hollows appear. The process of hollow formation depends on penetration of the tree's outer bark defences. This may be brought on by drought or wind damage, and subsequent entry by fungi and invertebrates which facilitate decay of the inner heartwood. Entry of decomposers and wood eaters also happens where self-pruning of branches occurs. This all takes time and progresses as the tree is growing bigger. Thus, only a large tree with ample time will contain very large hollows.[295]

Fire and forest structure at Kirth Kiln Regional Park, near Gembrook.

Shortly after a fire (1–3 years) the understorey is simple and uniform, typically consisting of species that can germinate and grow quickly.

As time passes. The slower-starting, taller shrubs, including *Banksia* sp. and *Hakea* sp., begin to emerge and overtop the early post-fire pioneer species.

At this site, not burnt for many years, *Banksia* and *Hakea* are vigorous, as indicated by the extent of flowering, and dominate the understorey. They will eventually die and another stage in the forest lifecycle will emerge but only if another fire does not occur.

Bushy Parrot-pea *(Dillwynia ramosissima)* produces more spines in response to browsing. © Chris Lindorff. CC-BY-NC 4.0 (Int).

Browse line on a Cherry Ballart (*Exocarpos cupressiformis*). Based on the lowest foliage height (dashed line), large numbers of Eastern Grey Kangaroos in this forest at Sandon, supported by surrounding pastures, are most likely to be responsible. © Stephen Platt.

Large trees provide a larger surface area of bark and greater canopy area and volume. This supports efficient foraging by birds such as treecreepers which are able to spend more time on a large tree with less time lost commuting between trees. Large old trees may provide flower resources (nectar, pollen) even in drought years that smaller trees cannot. Large trees are more likely to have a greater diversity of foraging resources such as dead limbs, decorticating bark, mistletoes etc. But large trees are always in short supply. To get to be large the tree must have lived for decades and survived innumerable threats. Only a few individuals survive long enough to be really huge. Those that do are of enormous value to wildlife.

Browsing by wildlife, such as Black-tailed Wallaby (*Wallabia bicolor*), can have significant effects on vegetation composition in foothill forests. It can affect whether seedlings survive, how they grow and the shape of the adult plant.[296] In a study at Mt Cole, approximately 60km east of the Grampians, up to 50% of regenerating eucalypts were eaten by browsing animals.[297] Plant structures, like spines and thorns, hairs and the protective film covering leaf surfaces (cuticle), as well as chemical defences, seek to prevent browsing. Their very existence indicates browsing's enduring significance as an issue for plants in this system. Fenced exclosures can be used to examine the effects of browsing by herbivores. They consistently demonstrate that more palatable species or life stages are preferentially affected by browsing and, in the presence of excessive numbers of browsing animals (overbrowsing), this leads to less palatable species or bare ground increasing.

Plant life

BLACKWOOD (*Acacia melanoxylon*) is a long-lived (80+ years) widespread understorey tree of foothill forests, particularly in moist gullies. Its dense foliage provides refuge to birds (e.g., daytime roosts for owls) and its seeds attract parrots, pigeons, ants and other seed-eaters.

Decaying Blackwood foliage is toxic to the seedlings of other plants (allelopathy) due to phenolic chemicals contained in the phyllodes (modified stems that look like leaves). Like all wattles – there are 183 taxa of *Acacia* in Victoria – Blackwood trees form an association with nitrogen-fixing bacteria (rhizobia), which form root nodules. This allows Blackwood to grow on sites with low natural nitrogen content.

Blackwood reproduces by seed and suckering from underground roots. Seed dispersal is a problem for all plants including Blackwood. Wattles produce large, heavy seeds with a thick seed coat that protects the inner embryo. They fall close to the base of the tree. Attached to the seed exterior is a fleshy treat (an elaiosome or aril), which contains fatty acids, amino acids and sugars, that attracts ants. The elaiosome, though small and light, contains about one third of the energy value of the seed.[298] Seed-harvesting ants collect the fallen seeds, up to 100% in some instances[299], and take them to their nest, using only the elaiosome to feed their larvae.

The dispersal of seeds by ants is termed 'myrmecochory'. The treat attached to the seed is shaped for easy carriage by the ant. Ants have been recorded carrying seeds up to 70–120m along roadsides, with an average of 12m.[300] In the process the seed is scattered and buried in a safe, nutrient rich location away from its parent (thus avoiding direct competition) and ready for germination. More than 1,500 species of Australian plants (87 genera, 24 families) reward insects for dispersal in this way.[301,302]

Blackwood seeds can remain viable for over 50 years. Other advantages to plant species of seed harvesting by ants include reduced predation by seed-eaters, such as pigeons, reduced direct competition between young seedlings and their parent plants, and avoidance of extreme temperatures and the direct effects of fire. The seeds may also benefit inadvertently from exposure to liquid antimicrobial secretions, produced by ants living in dense colonies as a defence against disease.[303] Fungi are a major cause of seed mortality.

The pink fleshy treat on Blackwood (*Acacia melanoxylon*) seeds attracts ants. © Stephen Platt.

Rhizobia on plant roots. © Frank Vincentz. CC BY-SA 3.0.

Meat Ant (*Iridomymrex purpureus*) transporting a Golden Wattle (*Acacia pycnantha*) seed. © Zsofia Palfi.

The heat of a fire or other disturbance will crack the thick Blackwood seed coat and, when rainwater reaches the embryo inside, stimulate the seed to germinate. With fire at appropriate intervals, Blackwood will continue to reproduce successfully. But too little or too much fire can eliminate these shrubs. Repeated fires at short-intervals can kill the juvenile plants before they are old enough (5 years) to produce seed. Too little fire and the shrub may grow old, die and not be replaced if its seedlings are unable to establish. Blackwood lives approximately 80+ years. Many acacia lifespans are much shorter. For example, the lifespan of Silver Wattle (*Acacia dealbata)* is about 25 years. Soil-stored seed allows wattles to persist between opportunities to regenerate.

Species of 'bracken' (*Pteridium* spp.) occur in appropriate habitats globally. The Australian species, Austral Bracken (*Pteridium esculentum*) is widespread in Victoria. *'Esculentum'* means edible (but see note regarding toxicity below). It is a hardy, native fern that can be abundant in friable soils with moderate rainfall and low fertility. The visible fronds are connected by underground stems (rhizomes) from which the roots arise.

Austral Bracken rapidly returns after the passage of a fire. The rhizomes survive a bushfire, as heat hardly penetrates into soil. Following post-fire rainfall, new fronds emerge quickly from dormant buds, allowing bracken to shade out potential competitors, including juvenile eucalypts.[304] In addition, dead bracken fronds produce chemicals that inhibit competitors.

Austral Bracken has been used as food by Aboriginal people in Australia – the rhizomes were pounded into a paste, roasted and eaten [but note that Bracken contains the known carcinogenic compound ptaquiloside[305]).

Bracken has played a significant role in human history – in glass manufacture, for soap and bleaching, as fuel, thatch, bedding, compost, fertiliser and medicine. It can be used to dye wool shades of yellow, red and brown. In medieval times, Bracken was cultivated as a fuel for firing kilns used in brickmaking but following the Black Death in Britain in 1348AD no bracken buyers could be found leading to a collapse of the brick industry. In 1636, the Earl of Stafford wrote on behalf of the king to the sherriff asking him to suspend the burning of bracken, which was believed to 'bring down rain' so that the king could enjoy pleasant weather.[306] In pre-Hadrianic Britain (<117 AD), bracken harvesting was a major activity of the community. It was used, with mosses, straw and leaves, as winter bedding. 'Conditions were apparently very insanitary. One study found that the bedding of a 30m^2 area contained half a million puparia of the stable fly.'[307]

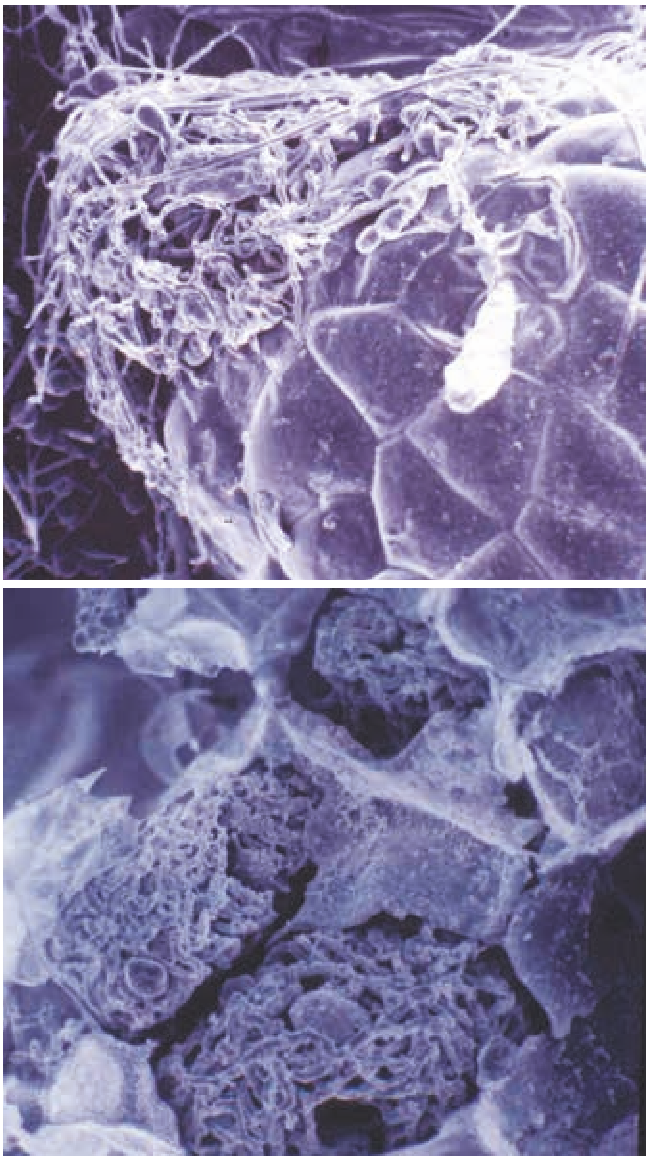
Frequent burning can lead to an understorey dominated by Austral Bracken. © Stephen Platt.

Enchantress of the plant world, its design is both alluring and deceptive. The Nodding Greenhood (*Pterostylis nutans*), found in colonies on the forest floor, emits a perfume that attracts its small insect pollinator – a gnat, fly, ant or mosquito. The insect lands on a platform at the entrance to the flower and walks inside. This is where the nodding mechanism is activated, trapping the insect as the hood nods down. A skylight created by clear cells at the top of the flower, draws the insect upward. On the way it squeezes past the orchid's pollen sacs which stick to the insect. This route leads to an exit. The insect flies away, allured by another fragrant greenhood. As it clambers through the second flower trap, the pollen sacs it carries are left behind and the plant is fertilised. The deception is complete.

The Nodding Greenhood is both masterful at deception and a trap. © Stephen Platt.

Once deposited, pollen tubes carrying the sex chromosomes will grow down the female reproductive stem (style). Net-like, extremely tiny orchid seeds will slowly develop inside an oval case. During summer it will split and the wind will scatter the seeds (appearing like dust).[308] As winter arrives, the orchid will transfer energy into storage as a tuber beneath the ground. In the soil it will lie dormant.

Orchids have developed a relationship with soil fungi (mycorrhizae) whereby the fungus helps supply carbohydrates to the plant and particularly the developing seed which has no reserves of its own.[309] The fungus is allowed entry to external cells of the developing orchid seedling but prevented from growing further.



Scanning Electron Micrograph of (left) mycorrhizal fungi on the surface of a developing orchid embryo and (right) the fungus coiled inside the outer Sunshine Diuris (*Diuris fragrantissima*) orchid cells.

Victoria's orchid flora is diverse with over 360 species, of which 110 grow no-where else (are endemic).[310] The original meaning of the word 'orchid' (etymology) comes from the Ancient Greek meaning 'testicle' after the shape of the tuber.

Fire is an important factor in stimulating flowering in some, but not all, orchid species including spider orchids (*Caladenia* spp.), donkey orchids (*Diuris* spp.), leek orchids (*Prasophyllum* spp.) and sun orchids (*Thelymitra* spp.) but not others, such as greenhood orchids (*Pterostylis* spp.).[311]

Looking a bit like a Christmas Tree and acting a little like a wildlife hotel, the Cherry Ballart (*Exocarpos cupressiformis*) is green, indicating photosynthesis, but when young also takes nutrients from a host plant, usually a eucalypt, via root attachments. That is, it is a partial parasite when young (hemiparasitic).[312] It is widely dispersed in sclerophyll forests, particularly on well-drained, shallow soils and granite outcrops. The fleshy, red 'cherry' (pedicel) attracts birds that help to digest and disperse the nut attached to it, which contains the seeds. It is edible to humans. The 'cherry' is actually a swollen stem. It has the highest sugar content of any native fruit in the forests of southern Victoria. Once ripened, the red fruits rapidly disappear as they are an attractive food source for wildlife.

Camera studies indicate that Native Cherry trees preferentially attract echidnas, possums, foxes, Swamp Wallabies, White-winged Choughs and Bronzewing Pigeons.[313] This may be because they create a microclimate of higher soil moisture, higher soil nutrients and reduced soil temperature beneath the plant. The dense foliage of this shrub is used by birds, including owls, for refuge. It is a host for some moths (e.g., *Orgyia anartoides*, *Philarista porphyrinella*).

The edible Native Cherry is a partial-parasite on other plants.

Native Cherry is highly palatable. You can observe the 'browse line' beneath tree-sized specimens or see the browsing damage as they sucker after fire (see page 147). The swellings, or cankers on some individuals are caused by fungi.[314]

The wood of Native Cherry was used by Aboriginal people to make spear throwers and bull roarers (wood attached to a rope that is swung around the head, used to create music and in ceremonies for communication). The sap was used to treat snakebite.[315]

Painted Apple Moth *(Orgyia anartoides)* caterpillar on a Native Cherry. Macleod, Melbourne. © Stephen Platt.

In the hills to the north east of Melbourne lives the rare Creeping Grevillea. © Stephen Platt.

Creeping Grevillea (*Grevillea repens*) is a rare plant of heathy forests on the outskirts of Melbourne. It resprouts after fire from a taproot. This plant is susceptible to a disease (*Phytophthora*) and overshadowing by other plants if fire is too infrequent.

Pale Vanilla Lily (*Arthropodium milleflorum*) is common in forests and woodlands. It develops underground tubers that were eaten by Aboriginal people. © Stephen Platt.

Magpie Moth (*Nyctamera amica*) on Dusty Daisy-bush (*Olearia phlogopappa*). © Stephen Platt.

Drooping Mistletoe (*Amyema pendula* subsp. *pendula*) is the most common mistletoe in southern Victoria.
© Google. CC SA 3.0 Unported.

The spectacular Mistletoebird (*Dicaeum hirundinaceum*) has a curious habit – it turns sideways on a branch to poop leaving the mess hanging on. The advantage of this behaviour only becomes evident when you know that their droppings contain seeds of the mistletoe plant, the berries of which are a major source of food. By unintentionally assisting with the distribution of mistletoe, the bird benefits by creating future food sources. The Mistletoebird and Painted Honeyeater (*Grantiella picta*), are largely dependent on the fruits of mistletoe. When not in fruit, mistletoe flowers are a favourite source of nectar for Eastern Spinebills (*Acanthorhynchus tenuirostris*) and other honeyeaters.

Male Mistletoebird. © Juliet Lowther.

Mistletoes are partially parasitic plants that grow after a seed attaches to a thin branch of a tree. There are thirteen native species of mistletoes in Victoria. They produce their own energy through photosynthesis but obtain mineral nutrients and water from the host tree.

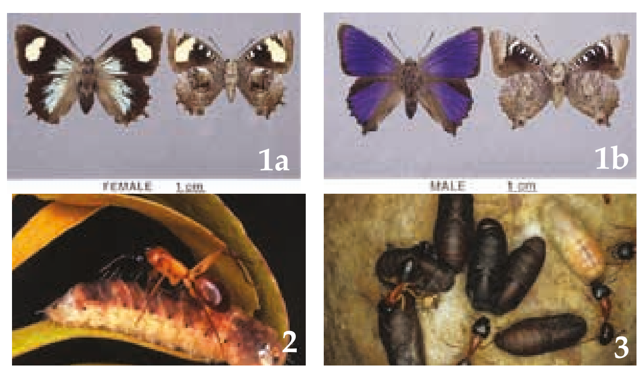
Most mistletoes mimic the host foliage. This may be a way of fooling potential leaf browsers, particularly the Common Brush-tailed Possum. If the host plant has chemical defences against browsing animals, then they may assume that so too does the mistletoe and avoid eating it.

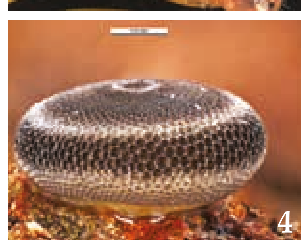
Australia-wide, forty-one species of birds have been recorded feeding on mistletoe flowers, mainly honeyeaters; and thirty-one species will feed on the fruits.

Mistletoe's dense foliage and solid, wide, woody attachment to the host creates an excellent place for possums, birds and other wildlife to hide from predators, and a strong base on which birds can build a nest – so check them out as you walk in the bush.

Some butterflies (e.g., *Ogyris* spp., *Delias* spp.) rely on mistletoe as the exclusive food source for their caterpillars. For example, the Genoveva Azure (*Ogyris genoveva*) caterpillar feeds at night on Box Mistletoe (*Amyema miquelii*) where it is attended by ants. The ants escort the caterpillars to their nest for daytime shelter and receive sugary secretions as reward from the caterpillar.

In healthy forest, it is possible to find dead mistletoes on live gums which indicate that mistletoe infestation is not a one-way decline for the host which has some capacity to resist a mistletoe. Many mistletoe clumps on a tree may be more a symptom of the host's poor health than the cause of its poor health. Fire may play a role in regulating mistletoe numbers in forests[316] with intense fire killing mistletoes but usually not the host tree. Drought also helps to control mistletoe, which has a higher water requirement than its host plant.





Stages in the life cycle of a Genoveva Azure butterfly. 1a &1b. Adults, 2. ant attending larva, 3. ants attending pupae, 4. egg case (scale bar 0.25mm).
© Museums Victoria 1,2 Rodney Start 3,4 Ross Field, 5 Simon Hinkllley CC BY 3.0 au

Animal life

Animals of the land

IMAGINE YOURSELF crawling into an underground labyrinth of dark, damp passages, not knowing what resident animal might be found there, not knowing if you'd get stuck. It was a 15-year-old schoolboy, Peter Nicholson, who first exposed the secret, underground life of the Common Wombat in 1960. Crawling deep into their burrows, armed with a torch, a mattock and spade, and half a kerosene tin for his collections, he sieved the floor dirt and collected wombat bones. He also charted the detailed architecture of burrows. This was done by driving pegs into the floor and stretching cord between them. Peter published his findings in the Geelong Grammar school magazine.[317]

In his book "The Secret Life of Wombats", James Woodford writes: "Wombats are the hobbits of the Australian bush, living underground and perceived as lazy and unadventurous. They are retiring solo folk, who give the impression of potential unfulfilled – neckless, stubborn, ferocious when cornered, intelligent, cute and mysterious."[318] Anyone who has left food in their tent at a popular campsite will understand that wombats have a keen sense of smell and a strong determination!

The Common Wombat (*Vombatus ursinus*) is widespread and common in eastern Victoria. Scattered populations exist in the far west. They occur from the coast to above the snowline. Common Wombats prefer open forests and woodlands with grassy creek and river banks for feeding, but rarely drink from freestanding water unless the grasses they feed on have dried out. Adult wombats rarely urinate except when scent-marking. Wombats are efficient swimmers over short distances.

Common Wombats build short-stay burrows and longer breeding burrows consisting of a network of tunnels, up to 18m long, some ending in a nest chamber of bracken fronds and bark. A burrow may have been used by many generations of wombats and be hundreds of years old.

Burrows are commonly dug into slopes or beneath rocks and provide protection from weather extremes. If you cannot fly away or climb a tree to shelter in a hollow, then burrowing is a good option to avoid predators, protect young and escape bushfires. Burrows are usually occupied by just one individual but may be used by several individuals over time.

Barbara Triggs, an authority on wombats, observed – "Crushed skulls of foxes and dogs have been found in burrows, evidence of the wombat's well-known method of disposing of intruders, and I have seen a fox chased out of a burrow by an angry adult wombat."[319]

The Common Wombat finds safety in a 'hobbit hole' but have you ever wondered what it's like to go inside? © Stephen Platt.

Mother and young wombat in their burrow.
© Mathew Higgins CC BY 3.0 (Au).

Juvenile wombat in its mother's pouch where it will live for around 6–10 months. © Matthieu Gauvain. CC BY 4.0 (Int).

A mass of processed grasses and sedges, wombats leave their pile of cuboid poo in full view and within sniffing height, often perched on a rock or log, to indicate the wombat's territorial claim. Its square shape is due to the elastic properties of the intestinal wall[320] but we can speculate that it makes stacking easier. © Stephen Platt.

After birth, wombats spend six to ten months in the pouch. Weaning from their mother may take another five to eight months. Adults can reach 40kg in weight and may live to around 15 years. Wombat courtship and mating occurs at night in the forest:

> "the male [chased] the female while she trotted around in wide circles and figures of eight; periodically she would slow down, allowing the male to catch up with her. After about two minutes the male delivered a powerful bite to the female's rump. At once, the female stopped running; the male then grasped her hindquarters with his forelimbs, rolled her over on her side and mounted her."[321]

Wombats live solo lives although territories can overlap.

The presence of wombats in a forest is easily recognizable because they leave their cube-shaped dung as a signpost on any prominent feature at bottom height, such as a rock or log. This, together with scent marking with dung and urine, serves as a territorial marker.[322]

Wombats themselves, due to primarily being nocturnal, are less often seen. They usually spend daylight hours asleep in their burrow, although they may sometimes be seen foraging in daylight during winter or at popular tourist campsites seeking food.

Common Wombats eat grasses, rushes, sedges and tubers. Moss and fungi may also be eaten. They often suffer from mange, caused by a mite (*Sarcoptes scablei*) that burrows through the skin.[323]

There is a long history of human persecution of wombats. In Victoria, a bounty of ten shillings per scalp was applied to wombats in 1925 and remained in force until 1966 when it was suspended.[324] Between 1929 and 1955, more than 60,000 bounties were paid. Even today, the Common Wombat is unprotected in many shires in Victoria.

An endangered Spot-tailed Quoll. © Jenny Nelson.

You might first realise that you are in Spot-tailed Quoll territory when you come upon a communal latrine, sited on a rock or log. Consisting of the dung of many individuals, the latrine has a distinctive odour.

The Spot-tailed Quoll (*Dasyusus maculatus maculatus*) is the largest marsupial carnivore on mainland Australia. They occupy territories of several hundred to several thousand hectares.[325] Hollow logs are most frequently used as dens. Rock crevices, burrows and tree hollows are also used.[326] Spot-tailed Quolls are great climbers. Active mainly at dusk and night, they will hunt for gliding possums in their tree hollows during daylight.[327] The diet of the Spot-tailed Quoll is dominated by medium-sized mammals including Common Brush-tailed Possum and bandicoot[328] as well as birds, reptiles and invertebrates. Larger mammals may be consumed as carrion.[329] Quolls live for around 4–5 years.

Top down or bottom up?

WHAT LIMITS population numbers of animals? Is it factors that lead to death – predation, disease or natural disasters (called 'top down') or food, habitat or space ('bottom up')?

The debate is unresolved, will depend on the system in question and its context and has led to its own field of study called 'population ecology'.

Agile Antechinus are prodigious breeders. © Matt Campbell CC.

Agile Antechinus with early-stage, pouch young.

Gould's Wattled Bat flying, and in a tree spout.

Consider what it would be like to be an Agile Antechinus (*Antechinus agilis*). As a female, life in the crowded hollow with up to 17 others is warm and cosy. It is hard to get to know who is there at any one time with up to 28 females and 24 males using the hollow at some time. During the 'rut', it is time for her to move and nest alone or join a small, all-female commune. It is her decision where and when mating will occur and it isn't going to happen in the mixed commune! After mating, her male partner will live just a short time before he and all other adult males die, their energy expended. As her pregnancy progresses, she will leave the commune to find a tree cavity in which to give birth alone and to rear her six to ten young (lower in coastal and predictable environments, higher in seasonal). She may take half her young to a nearby hollow for added safety. As they gain independence and join a new commune she will most likely die like her male partner before her. Although having the capacity to do so, only a few females survive to a second year. After a time in the shared tree cavity in eucalypt forest, it will be necessary for the commune to leave the parasites behind and find a new hollow in a better habitat, perhaps on the river flats or in a tea tree wetland.[330]

Agile Antechinus are widespread in the forests of Victoria, nocturnally active and insectivorous. They could easily be mistaken for an introduced House Mouse but are not related. They are the smallest animal in the world to reproduce just once (males) before death (females can reproduce for two years).

Male antechinus die due to the energy expended in mating and the effect of physiological changes relating to managing stress. This odd strategy may be driven by sperm competition. The argument goes like this – a short breeding season coincides with maximum food availability in which females reach peak ovulation at the same time, if not the same day, and promiscuously mate with males. This has led to large male testes and maximum energy expenditure by males to succeed.[331] That is, you've got to get your sperm to her eggs before the competition do, so everything is invested in that outcome. The energy and physiological cost of doing that is so high it leads to their death.

Weighing in at around 14 grams, Gould's Wattled Bat (*Chalinolobus gouldii*) is hardly a heavyweight. Its diet consists of a wide range of invertebrates. Small colonies may be found in the spouts of large living trees.[332] During winter the species goes into torpor. Females become pregnant in spring and suckle their young over November–December. The young become independent in January. Gould's Wattled Bat is very common around Melbourne with nest boxes in several parks almost exclusively occupied by this species.

A Powerful Owl making a meal of a Sulphur-crested Cockatoo.[333] No wonder that these large parrots are cautious when finding places to sleep at night! © Juliet Lowther.

The Powerful Owl (*Ninox strenua*) is our largest owl and a formidable predator, primarily of arboreal mammals.

Greater Glider, Sugar Glider, Eastern Ring-tailed Possum (in urban and coastal areas), and large birds such as Australian Magpie are consumed.[334] Common Brush-tailed Possums are also eaten but primarily in urban environments. There is only a minor dietary overlap with Masked Owls which prey on small mammals of the forest floor.[335]

During a study of Greater Gliders in NSW, the study population of gliders was stable at ~80 individuals until Powerful Owls moved in. Over the following four years it plummeted to one tenth, or around eight individuals. At that point the owls moved on to raid another larder within their home range.[336] Hence, the prey population had an opportunity to recover.

Ed McNabb, who studied two pairs of Powerful Owls near Melbourne, one for three years, the other for fifteen, found that every one and a half days a major food item was taken. One resident, breeding pair of owls took 95 major prey items in a year. Recent work suggests that this may be an underestimate. Powerful Owls roost in dense vegetation hoping to avoid mobbing by daytime birds. They nest in large hollows of very old trees (>350 yrs) usually in a gully. Nest trees are changed regularly (one pair used seven in 15 years). In this study, regularly used parts of the home range covered around 300ha.[337]

Changes in the diet of the Sooty Owl have given us insights into changes in forest ecology of East Gippsland. © Rohan Bilney.

In the caves of East Gippsland, Rohan Bilney, while undertaking his PhD studies, unearthed a murder mystery. In this case the murderer was a Sooty Owl (*Tyto tenebricosa tenebricosa*) and the victims, species of mammal that are now regionally extinct or occurring in vastly fewer numbers. Sooty Owls prey on a wide range of mammals up to 1.5 kg. Like other birds of prey, they cough up a pellet comprising fur, bones, feathers or whatever couldn't be digested and sometimes these accumulate in caves. By examining recent pellets below owl roosts and comparing them with the sub-fossil bone deposits found in caves (representing the former diet of Sooty Owls), Rohan was able to piece together recent changes to the mammal community of East Gippsland. He discovered that the mammal community that currently exists is markedly different to how it was prior to European settlement, with 18 out of 28 species no longer contributing to the Sooty Owl diet in the study area. It appears that three quarters of the mammal species have undergone significant changes in abundance and/or distribution, with ground-dwelling species most affected. To compensate for this loss of prey species, Sooty Owls have increased the proportion of gliding possums they eat from half (55%) to four-fifths (81%) of their diet.[338,339,340,341] The potential implications of these mammal losses for ecosystem function and health are profound.

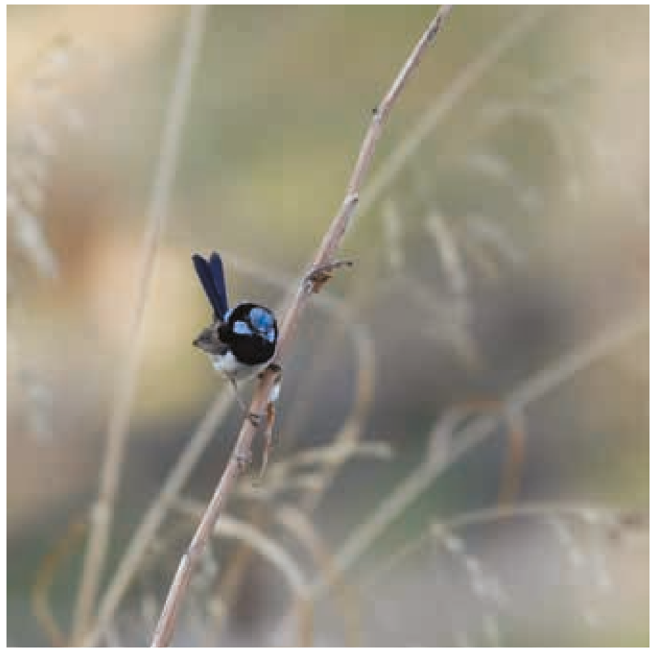
Sooty Owls are often found along gullies and streams in wet forest associated with tree ferns and Blanket Leaf (*Bedfordia australis*) whereas the Powerful Owl, a larger species, is more likely to be found in mature, dry, temperate forest with many live, hollow-bearing trees and diverse habitats.[342]

Sooty Owl. © Tim Bawden CC BY-NC 4.0 (Int.).

White-throated Nightjar. © Surfap CC-BY-NC 4.0 (Int).

White-throated Nightjar chick. © The Myall Mob. CC BY-NC.

White-throated Nightjars (*Eurostopodus mystacalis*) inhabit dry to moist eucalypt forest, mostly on ridges and slopes with a stony substrate and leaf cover. As a ground nester, it makes sense for this bird to use a stable ridge nest site away from potential flooding. They are nocturnal, catch insects and drink while in flight.



Endemic to eastern Australia, the tiny Superb Fairy-wren (often called a Blue Wren) forages in groups on the forest floor looking for invertebrates. After years of study, we know a lot about their life history and it's not what you might expect. © Juliet Lowther

Superb Fairy-wrens (*Malurus cyaneus*) live in small family groups but their simple family life masks a propensity for infidelity. The dominant male, resplendent in his blue breeding colours, and the female, are accompanied by dull brown young 'helper' males from previous broods that remain in the territory of their birth (natal territory). This is called co-operative breeding and occurs in about 3% of birds (e.g., Laughing Kookaburra, Apostlebird). By helping, subordinate males avoid expulsion from the family group and likely death. They may also gain vital parenting skills that will help them establish their own territory in the future. There is no evidence that this arrangement helps breeding success in Superb Fairy-wrens. Helper males that temporarily stray from the group are punished by the dominant male.[343] Experiments suggest that helpers would leave the group if females were available and there was habitat sufficient to support them.[344] Their sisters, potential competitors with their mother, are chased away by her as they mature. Most will die. A few will find an available territory and establish a new family group.

Male Superb Fairy-wren. © Stephen Platt.

Grey Butcherbird (*Cracticus torquatus*). © Stephen Platt.

A male and female wren will remain together throughout the breeding season giving the appearance of a faithful pair bond and raising successive broods. However, genetic analysis has shown that infidelity is rife, more so than for any other bird species except Australian Magpie.[345] During the breeding season, the female frequently leaves the group under cover of darkness to visit other males in nearby territories, those that became blue earliest in the year[346], a sign of their health and fitness. These 'fitter' males will attract many of the local females and may father up to 70% of the year's offspring. Thus, up to 76% of a clutch of eggs may be sired by other male fairy-wrens that contribute no care to these offspring. Almost all (95%) broods of Superb Fairy-wrens contain young sired by males outside of the family group.[347] She is able to make this choice to mate with other males, because of the efforts of the helper males who release her from some responsibility for raising her young. The dominant male, though raising young that are not all his own, can also benefit from this networked breeding system if other males raise the young he has sired. The adage 'don't put all your eggs in one basket' seems to apply here. The helper males also benefit by siring 10–20% of offspring across nests, higher rates being associated with lower attractiveness of the dominant male.[348] The number of eggs laid per clutch (3–4) is higher in years of greater rainfall. Dense and difficult to access low shrubs, such as blackberry brambles, conceal nests that fledge a greater number of young, the brambles probably providing both reduced access by predators and concealment from nest parasites, such as other wrens and cuckoos.[349]

Female fairy-wrens call to their eggs in order to teach the unborn young a 'family code' they use later when begging for food. It is believed that this helps the parents to recognise the young hatched in their nest and to avoid brood parasites like Horsfield's Bronze-cuckoo (*Chrysococcyx basalis*) and other wrens. Cuckoos lay their eggs in the nests of other birds, thereby saving themselves the effort of rearing young. Though laid in the same nest, the cuckoo eggs receive less exposure to learning the Fairy Wren code as they may be deposited after the lessons cease.[350]

The dominant male wren displays his bright blue plumage only during the breeding season in order to attract mates. However, this colourful display can come at a cost. Bright colours attract predators such as Kookaburras, Grey Butcherbirds and Pied Currawongs. Breeding males adjust their risk-taking behaviour in order to survive. They flee more readily on hearing bird alarms and take longer to emerge than in the non-breeding period.

Monogamy versus polygamy

WHY DO some animals apparently choose only one sexual partner for at least a season, if not for life, whilst others have many partners? Polygamy is widespread in animals. By having many mates there is a potential genetic advantage for the polygamous male – more offspring, more chance that at least some mates offer genetic advantages. Some species, such as the Superb Fairy-wren, are socially monogamous and appear to have one partner but genetic tests show that they are not sexually monogamous, in fact anything but!

Monogamy is more common in birds and freshwater fish where parental care requires time and effort. It is less so in reptiles, with an exception being the Stumpy-tailed Lizard (*Tiliqua rugosa*).351 Their social mate sires 86% of young, but there is little parental care. Most of these lizards (66%) reunite with the same partner to breed over many years (5–15 years). Strong pair bonds are formed many weeks before breeding and these allow an early start to mating (two weeks earlier).

Possible situations that favour monogamy as a breeding strategy include:

- Spatial constraints – where two individuals are needed to defend a territory and females are dispersed over a wide area
- Time constraints – the need for males and females to be fertile at the same time and the length of breeding season – requiring synchronous breeding and giving less time to find other mates
- Parental care – the additional parental support in a monogamous relationship may result in more offspring surviving and so select for monogamy
- Genetic constraints – monogamy may be more likely if genetic benefits arise from selecting and maintaining bonds with a single partner.[352]

Monogamy or polygamy? Well, it's complicated and very much determined by the specific circumstances of the species.

The Shining Bronze-Cuckoo (*Chrysococcyx lucidus*) has two tricks 'up its sleeve'. The first involves popping into the nests of other birds, preferably those with a domed nest design, such as a thornbill, to deposit an egg. The deceived nest-builder then incubates both its own eggs and that of the interloper. After hatching, the young cuckoo ejects the host chicks from the nest and is raised by its adopted parents. The second trick relates to diet. The Shining Bronze Cuckoo, like some other cuckoos, specialises in eating insects and their larvae but particularly hairy caterpillars and ladybird beetles. The cuckoo manipulates the caterpillar in its beak to separate the hairy skin from its innards.[353] The Shining Bronze Cuckoo is a fairly common bird of the forests and woodlands of Victoria.

The Shining Bronze Cuckoo has some clever tricks under its wing. © Julius Simonelli. CC BY-NC 4.0

Fan-tailed Cuckoo (*Cacomantis flabeliformis*). Cuckoos specialise in eating hairy caterpillars. © Juliet Lowther.

◀ Weasel Skinks lay their eggs in communal clutches with other skinks. © Reiner Richter. CC BY 4.0 (Int.).

When should you put all your eggs in one basket? Some small forest skinks lay their eggs together in a communal clutch. This seems at odds with the risk that they will be preyed upon. The Delicate Skink (*Lampropholis delicata*), Garden Skink (*Lampropholis guichenoti*), Weasel Skink (*Saproscincus mustelinus*), McCoy's Skink and Eastern Three-lined Skink exhibit this behaviour. Warm, humid, natural cavities under logs or rocks are ideal locations for laying their soft-shelled eggs.[354]

You are most likely to come upon a Giant Burrowing Frog (*Heleioporus australiacus*) after rain in suitable habitat but your timing will need to be precise. During the breeding season, males call from burrows on the edges of streams to attract females. The couple spends less than six days a year at the breeding site. Eggs are laid in streamside burrows and washed into the water during heavy rainfall. Depending on seasonal conditions, the tadpoles take 3–11 months to develop. Non-breeding activity areas for these frogs are located 20–250m from the breeding site in forest and this is where they will spend most of the year. They use up to 14 burrows for shelter in a 500m^2 area.[355,356] Steep areas and forest with dense phytofall are avoided.

The main prey of the Tiger Snake (*Notechis scutatus*) is frogs but it will also take other small vertebrates and can climb trees to catch nestling birds. It is widely distributed in Victoria and often found near wet areas and along watercourses. Mainly active by day, it may remain so on warm nights. During mating in spring or autumn, males may engage in ritualised combat, entwining together in a demonstration of strength. Females give birth to up to 37 live young. The Tiger Snake is an extremely dangerous animal with a venomous bite that may be fatal to humans.

Communal skink nest. © Peter Robertson.

Giant Burrowing Frog. © Rohan Bilney.

This Tiger Snake is using its strong sense of smell to locate Silvereye chicks in a hidden nest. It slithered by me then climbed silently among the branches whilst the parent Silvereyes fluttered about in alarm. © Stephen Platt, Crawford River.

The large mandibles indicate that this is a male Golden Stag Beetle (*Lamprima aurata*). These beetles feed only on dead wood. © Simon Grove. CC BY-NC-SA 4.0 (Int).

Emperor Gum Moth. © Ethan Beaver. CC-BY-NC 3.0 (Au)

Like a magician's trick, the Emperor Gum Moth caterpillar spins its cocoon and, months later, will emerge transformed into a moth – how amazing! © Fir0002 CC SA 3.0 Unported.

The Emperor Gum Moth (*Opodiphthera eucalypti*) builds a silken, waterproof cocoon in which to change (metamorphose) into its moth form. When a baby bird needs to escape its egg, it has an air supply inside the shell and an 'egg tooth' to help break the shell. But what about a moth? In this case, the adult moth regurgitates a fluid to soften the cocoon and then cuts a hole using sharp hooks on each forewing. The cocoon has a series of openings along the side to admit air. Usually, the moth will appear in spring-summer following the winter in which the cocoon was made. However, if conditions aren't conducive to emergence, it may stay cocooned for 2–5 years. In one case, a moth emerged after 10 years. The emergent moth only lives a couple of weeks, does not eat, and has the sole purpose of mating and laying eggs.[357] The wings of this large moth have prominent 'eye' markings that probably serve to startle would-be predators. Caterpillars undergo colour changes at each of the five stages of their development starting off black and ending up with a brilliant green and blue body.

Native paper wasps, of which there are 35 species in Australia, build a hanging nest of saliva and wood pulp in a dry location such as a rock overhang or under a tree branch. The female wasp establishing the nest becomes a queen and breeds numerous workers that help with nest building and raising larvae. Wasp larvae are fed on caterpillars collected by the adults. Adults feed on nectar and are important pollinators. They will aggressively defend the nest and should be avoided.

Common Paper Wasp and nest (*Polistes humilis humilis*)
© Reiner Richter. CC-BY 4.0 (Int)

Life cycle of the Imperial Blue Butterfly

Imperial Blue Butterflies mating. © Russell Best. CC-BY-NC 4.0 (Int).

Eggs of the Imperial Blue Butterfly.
© Linda Rogan. CC-BY-NC 4.0 (Int).

Imperial Blue caterpillars attended by ants on a wattle leaf.
© Argybee. CC-BY 4.0 (Int).

Emerging Imperial Blue butterflies.
© Adam Edmunds. CC-BY-NC 4.0 (Int).

Imperial Blue chrysalis attended by ants.
© Chris Lindorff. CC-BY-NC 4.0 (Int).

The Imperial Blue Butterfly (*Jalmenus evagoras*) lives in bushland east of Melbourne. Its caterpillars are attended by ants. To examine why they are present, ants were removed from some shrubs on which caterpillars were living whilst others were left alone. The caterpillars without ants were preyed upon by mud wasps, bulldog ants, spiders and bloodsucking bugs. Most died. Of those living nearby with ants, some 70–95% survived. Clearly the butterfly benefits from the ant's protection.[358] But why do the ants help out? The caterpillar exudes a sugary mixture from a gland on its back that is full of amino acids, the building blocks of proteins. They are so rich that the ants ignore other sugar offerings by wattle nectaries and sap-sucking bugs.[359]

But how do the ants and butterflies meet? Emerging butterflies have to seek out their food plant, a wattle. They are also attracted to the remains of last season's pupae where they might find ants. Lastly, they look for host plants with treehoppers (related to cicadas and leafhoppers) that produce a sweet waste that attracts the right ants. Young larvae hang out with older ones that already have attendant ants.

Male Imperial Blue Butterflies have been seen gathering around pupae and mate with females as soon as they emerge.

Thus, the lives of the ant, the butterfly, the host wattle and their environment, including fire needed for wattle regeneration and the bacteria it needs to extract soil nitrogen, are intertwined.

Sawfly larvae congregate during the day for mutual defence. © Stephen Platt.
Adult Sawfly. © Suzanne Jones. CC.

In late winter and spring, they are often first seen as a writhing mass of black bodies flailing about with yellow-green drops of smelly, irritating liquid oozing from their mouths. During daylight Steel-blue Sawfly (*Perga affinis*) larvae use group and chemical defence against predators.

They are known as 'spitfires' although they don't actually spit. However, they have a pouch inside their foregut from which they regurgitate fluid as a deterrent to ants, birds and mice that might otherwise attack them. The fluid is made of the oils obtained from their eucalyptus-leaf food.[360] At night they disperse to feed on their eucalypt host plant. When small, the damage they cause looks like a leaf blister; when they are larger, whole leaves are eaten and host plants defoliated, particularly topmost new growth. When fat enough, they pupate in a cocoon in leaf phytofall. After emerging as a flying adult sawfly in summer-autumn, the female mates then uses her saw-edged tube (ovipositor, hence the name sawfly) to slit open a leaf surface or stem and insert her eggs. Thus, the cycle begins again. There are many sawfly species worldwide.[361,362]

But there is another side to sawflies, a tale of beauty and the beast. Male sawflies are pollinators of the Large Duck Orchid (*Caleana major*). The sawfly is lured in by an attractive perfume. The hood (head of the 'duck') tilts forward to entrap its visitor, pollen is deposited on its body and it is released. It's a fascinating example of the complex interrelationships in nature. If the gum trees that sawflies rely on are unhealthy, it's not just the sawfly that is affected but the orchids that rely on it.

Large Duck Orchids trick adult male sawflies into 'intimate relations'. © Reiner Richter. CC-BY 4.0 (Int).

Black-faced Cuckoo-shrike eating a sawfly caterpillar. © Juliet Lowther.

Like mafia mobsters, ants offer protection in return for sugary honeydew produced by insects such as these Black Gumleafhoppers (*Eurymeloides* sp.) © Stephen Platt.

Black Rock Scorpions shelter under rocks. © Stephen Platt.

She carries her young on her back for the first days to weeks of their life. The Black Rock Scorpion (*Urodacus manicatus)* lives in open forests and woodlands under rocks or logs in a shallow (10cm) burrow. The entrance may be covered with a stone. Beneath the entrance is a cleared space called the 'living area' where feeding and mating may occur. Scorpions eat ground-living invertebrates. This species waits at the burrow entrance and ambushes passing prey, sensing its vibrations. Most scorpions glow a blue-green light under moon or ultraviolet light. We don't know why but it has been speculated that this might act as a sunscreen, warn off predators, help to find partners in the dark or protect them from parasites.[363] Their sting is painful but unlikely to be fatal.[364]

Black Rock Scorpion (*Urodacus manicatus*) under ultraviolet light. © Heath Warwick, Museums Victoria. CC BY 4.0 (Int.).

The white curl grub of a scarab beetle; beetle pupa (both normally buried in soil) and adult Cowboy Beetle. © Stephen Platt.

Invertebrates are more complex and possess abilities beyond what we generally give them credit for. Whilst digging in my suburban garden, I came across the crescent-shaped 'curl' grubs (larvae) and encased pupa of a beetle. The larvae feed on plant roots until they pupate, during which time they change into an adult beetle. I also came upon an adult beetle which, after examining it, was placed outside in a container holding soil, so that it could fly off. To my astonishment, within seconds the air was abuzz with several male Cowboy Beetles (*Chondropyga dorsalis*) presumably attracted to a chemical signal (pheromone) emitted by my female (who proceeded to bury herself rather than fly off). I had never seen this beetle previously but now had several flying about. She left along with her suitors and I haven't seen them since.

Velvet Worms have ancient origins. © Carolyn Platt.

Australian Garden Mantis (*Orthodera ministralis*). © Andrew Allen. CC-BY-NC 4.0 (Int).

Mantis egg case. © Donna Tomkinson. CC-BY-NC 4.0 (Int).

Velvet Worms (*Onychophora*) catch their insect prey by squirting an adhesive slime. They live amongst the phytofall of moist, humid forests. Similar-looking animals occurred in the marine environment over 500 million years ago (early Cambrian). Some species bear live young and some males place sperm on their head prior to inseminating the female.[365]

It's not a relationship 'made in heaven'. After a lengthy mating, in about 16% of encounters[366], female mantids eat their partner (sexual cannibalism), thereby taking advantage of his energy value, if not his company. This enables her to put on weight and produce up to 40% more eggs. Females lay their eggs as a single mass inside a hard, woody case (*ootheca*).

Many praying mantises are stick-shaped, and green or brown in colour. This helps to camouflage them with their surroundings so that they are not noticed by predators. It also means they can sneak up on their prey! The praying mantis is a predator that ambushes its prey. It stays very still, holds its front legs in the air, then when it sees something tasty, it moves towards it with a swaying movement. Then, when close, it attacks with lightning-fast speed. A praying mantis primarily eats invertebrates. Some species of praying mantis have been seen eating mice, bats and even small birds! If it feels threatened, the praying mantis may display warning colours on the inside of its wings, release noxious odours, and even 'box' with its front legs!

Just dips in the sand? Far from it. These funnel-shaped traps were made by antlion larvae (Myrmeleontidae). The larvae lie buried at the bottom of the cone waiting for an ant to slide down the grip-free surface. There it will be pierced by the waiting antlion's jaws and its contents eaten. The winged adult antlions live very short lives. © Stephen Platt.

Antlion larva. © Graeme Cocks. CC-BY-NC 4.0 (Int).

Winged adult antlion.
© Reiner Richter CC-BY 4.0 (Int).

Burnt branches embedded in the centre of this termite mound indicate a previous fire. A couple of years after that fire, termites would have arrived and built the mound we see. The forest has been burnt again very recently as shown by the blackened landscape. This will have damaged more trees and created new opportunities for termites to infest them.
© Stephen Platt.

Termite life-history begins with a *winged* male and female. They, as 'king' and 'queen', will start a new colony by flying off and finding a suitable new site. After mating, the queen will lose her wings, excavate the first passages of the new mound, grow very large and become a prolific, underground, egg-producer. Immature termites will turn into sterile soldiers or workers, or winged alates that fly away and start new colonies.

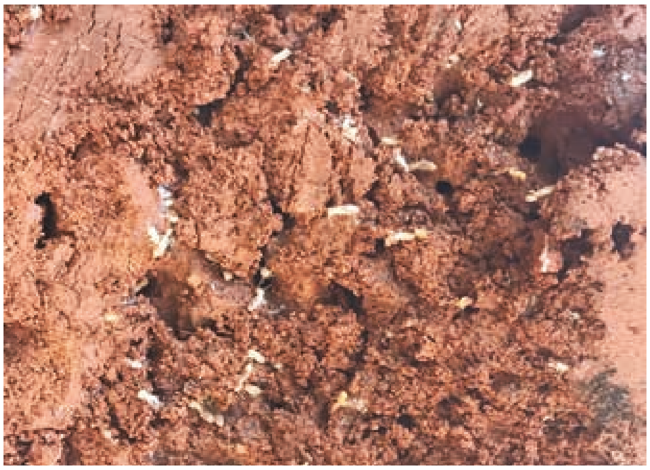
Termite queens have the longest known lifespan of any insect, living for 30 to 50 years.[367]

Most termites are blind and rely on chemicals for communication used when alarmed, to mark trails, and send sexual signals. Ants are their greatest predator.

They feed on dead plant material and are important ecologically as recyclers. Microbes in their gut do the hard work of digesting cellulose from plants. Termites evolved from wood-eating cockroaches and the first clues to this evolutionary relationship was similarities in their gut microbes.

Termite mounds in East Gippsland are used by Lace Monitors to incubate their eggs. The warmth is provided by the activities of the termites. Without them the climate in Victoria is too cold for egg incubation. The Monitor returns at hatching time to release her young from inside the mound.

Termite mounds are covered in a dense layer of clay. Inside are open galleries.
© Juliet Lowther.



Termites are blind so it doesn't matter that the lights are off inside their mound. © Stephen Platt.

Large Pink-winged Stick-Insect *(Podacanthus typhon)*, East Gippsland. Female stick insects can produce fertile eggs without mating (parthenogenesis) and the eggs will hatch into females. © Geoff Boyes CC-BY-NC 4.0 (Int).

Some stick insects lay eggs that mimic seeds. They trick ants into taking them to their nest where they are guarded. Some young stick insects even look and behave like ants.
© A. Healy, Australian Museum.

Common Spotted Ladybird (*Harmonia conformis*) © Reiner Richter CC-BY-NC 3.0 (Au)**; 2. Larva** © Reiner Richter CC-BY 4.0 (Int)**; 3. Congregation of Common Spotted Ladybirds** © Scottgze CC-BY-NC 4.0 (Int)**; and 4.Eggs** © Reiner Richter CC-BY 4.0 (Int).

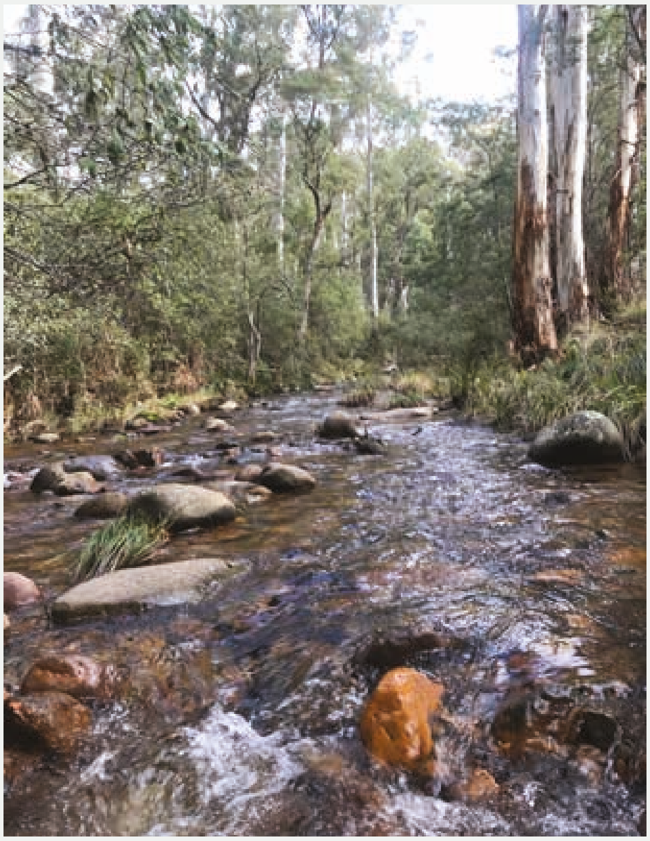
Female Common Spotted Ladybirds lay their eggs near a colony of aphids, on which their larvae, which hatch after four days, will prey. They eat around 200 aphids over four weeks then attach to a leaf and pupate for one week before emerging as an adult. There are around 500 species of ladybird in Australia.[368] Lifespan is climate dependent and between two months in warm climates or up to two years in cold climates. Cold climate species aestivate (are dormant) over winter. Longevity is also linked to 'prey synchrony' or emergence at the time that prey is available and vulnerable. Mating may take minutes to days. Some species of ladybird, including the Common Spotted, are known to congregate together in summer or winter. Overwintering ladybird congregations begin with a beetle selecting a suitable site. It then emits a pheromone to attract other beetles, which congregate with it. I have seen this inside a cave at Cape le Grand National Park in Western Australia. Thousands of ladybirds covered fallen rocks on the floor of the cave.

Animals of upland rivers

UPLAND RIVERS tend to be fast-flowing, with turbulent water flowing through boulder riffles at intervals interspersed with relatively shallow, still pools containing pebbles, sand and submerged phytofall. The water is clear, often shaded, cool and well oxygenated. Floods occur rapidly, inundate gravel banks, then subside just as quickly. Waterfalls, fallen logs and other potential barriers to movement occur. The banks are usually lined by rushes and reeds, ferns and shrubs such as tea tree (*Leptospermum* spp.). Upland rivers differ markedly from lowland rivers which tend to be wide, deep, often silt laden and muddy-bottomed.

In upland streams, but only at the very headwaters in the Central Highlands of Victoria, you can find the militarily-striped, amber-coloured Barred Galaxias (*Galaxias fuscus*). These small (5cm) fish lack scales and are resident (non-migratory). They deposit up to 500 eggs under cobbles in shallow pools above a riffle zone.[369] Barred Galaxids consume invertebrates and live for up to 13 years. The species has declined and disappeared from streams at lower elevations due to predation by introduced trout. Barred Galaxias are listed as 'critically endangered' as the remaining populations on Earth are confined to a small area of the Central Highlands. The stream headwaters they occupy are above a natural barrier, such as a huge log or waterfall, that prevents upstream movement of trout. Wildfire is also a problem when ash and sediment wash into waterways post fire, usually following a drought that has reduced water flows.

Platypus (*Ornithorhynchus anatinus*) occur in upland and lowland rivers and large wetlands throughout most of southern Victoria. Being aquatic, Platypus are mainly confined to a linear territory – movement is either upstream or downstream. Male Platypus defend a section of river and are equipped with poisonous spurs on their hind legs for fighting with rivals. Sub-adult males that unsuccessfully challenge for the territory and its resident females may be evicted, and in some cases killed, by the resident male. As young Platypus mature, their parents will evict them from the stream of their birth (natal stream). They must evade resident males and search for an unoccupied territory. This may involve trekking overland. One sub-adult male was detected moving 55km along a river. It's a tough start to life.



A typical upland river – the Dandongadale River, approx. 20km SW of Mt Buffalo. © Stephen Platt.

Barred Galaxias live in high mountain streams. © Tarmo A. Raadik.

How far do you think a Platypus travels along a river?
Source: wallpaperaccess

Poisonous spur on the hind foot of a Platypus.
© E. Lonnon. CC SA 3.0 Unported.

There are ways to increase your chances of seeing a Platypus. Ideally, the stream will have large and small cobbles with intermittent pools. The cobbles are refuge for the invertebrates the Platypus prefers to eat. The bank will be lined with trees and shrubs with interwoven roots that bind the soil together and provide cover and shade. This is ideal for constructing resting and nesting burrows, and for protection when Platypus leave the water. Lastly, you will need to sit very quietly, preferably at dawn or dusk looking for what looks like a floating log but this one may be making ripples and will regularly disappear beneath the surface. Platypus are mainly active at night but may be active at other times, particularly when the weather is overcast in cooler months.

Our perspective on this extraordinary animal has changed with time. "I never saw the skins used for any other purpose than making tobacco pouches," wrote Horace William Wheelwright in 1862. Yes, he was talking about Platypus. The Platypus was given its scientific name, *Platypus anatinus* (flat-foot duck), in 1799 by George Shaw, a parson turned Keeper of the Department of Natural History of the Modern Curiosities of the British Museum. In November 1896, Platypus were being "… destroyed wholesale".[370] "The skins which were necessary to form a Platypus rug were now worth 15 pounds".[371]

A Platypus skin coat made of 42 skins.
C. Barrett, 1944. The Platypus. (Image originally supplied by Planet News Ltd, London). Public domain.

Legal protection of wildlife

The first legislation, in 1888, to protect a native animal in Victoria was for Platypus.[372] The Koala was proclaimed in 1898. It wasn't until 1975 that all wildlife was protected (unless declared unprotected) by the *Wildlife Act 1975*.[373]

There is a legislative oddity that shows the attachment people can have to wildlife. 'Edward' an orphaned Koala, rescued by Florence Roberts in 1936, died in 1944. An Act of Parliament [Game (Koala Protection) Act 1938] was passed so that the Phillip Island Historical Society could retain Edward mounted in a case.

'Edward' was so adored by the Victorian public that an Act of Parliament was proclaimed to allow his remains to be kept.[374]
Image source: Museums Victoria.

Fur, a characteristic of mammals, keeps Platypus warm as they dive underwater for freshwater invertebrates: shrimps and crayfish (yabbies), water bugs and diving beetles, worms and mussels, and immature dragonflies, mayflies, true flies and caddis flies, tadpoles and small frogs, and fish. When underwater, prey items are held in cheek pouches. To detect prey, Platypus bills are equipped with electro-receptors which can sense the tiny electric currents created when many of their prey species move. They can stay underwater from five to ten minutes without drowning and will rapidly move away after detecting danger. Gravel is used to help masticate food in the cheek pouches as Platypus do not have true teeth. Platypus do not have a stomach either. Most of their day, up to 17 hours, is spent sleeping in a burrow. Platypus burrows come in two forms. 'Nursery burrows' are used for breeding and 'camping burrows' are used for shelter.

Camping burrows are quite short (1–3m long). The entrances are usually difficult to spot, being located underwater or just at the water surface, often beneath a fallen log or undercut bank or stump. An adult will use several different camping burrows and may occasionally share a burrow with another grown Platypus, though males and females both tend to be solitary in their habits. Platypus sometimes shelter in hollow logs or dense accumulated river debris.[375]

Nursery burrows are 3–15 metres long, with one or more oval entrances located well above the waterline. It may be that nursery burrows are placed relatively high up along a bank in order to help protect young Platypus from drowning in floods. Platypus have strong claws on their front feet and are well suited to digging. It has been calculated that they can complete one metre of tunnel in about two hours.

The home ranges of individual Platypus overlap and so several individuals may be found in a stretch of river. Females have a smaller range than males. In a study of Platypuses in the Yarra River catchment, the home range of adults was 2.9 – 7.3km long. Juveniles travelled less, under 1.7km. Individuals travelled over 10km (males) or 4km (females) whilst feeding overnight. Burrows were 0.4 to 3.7m long and usually hidden by vegetation along undercut river banks.[376]

Estimates in rivers near Melbourne put the density of Platypus at around 1.3–2.1 adults per kilometre of stream. In the Yarra River, one sub-adult Platypus moved its home 43km over two years and, in the Wimmera River, another moved 48km. This is likely to represent young seeking unoccupied territory as they become sexually mature. Platypus are good climbers and can scale a vertical waterfall.

Along with echidnas, Platypuses are the only mammals to lay eggs. Platypus breed from August to October. Male Platypus will fight using their poisonous spurs for exclusive access to females. Courtship involves the male grabbing her tail, and her his, followed by swimming in circles. A female lays one to three eggs, which are incubated between her belly and curled-up tail. The eggs are 15–18 millimetres long and have a parchment-like shell, like those of snakes and most lizards. After hatching, the young are fed milk for about four months, and first enter the water in January to March. When grown, male Platypus measure an average 50cm in total length (bill tip to tail tip) and weigh 1,200–2,600g. Adult females are smaller, measuring an average 44cm in total length and weighing 600–1,600g.

Platypus respond to floods by constructing an earth plug at the entrance to a breeding burrow. However, severe flooding, especially where bankside vegetation is degraded, can expose the burrow, and drown young and adults.[377],[378]

Natural predators include snakes, large eels and birds of prey.

Platypuses are survivors. Their relatives survived the split up of Gondwana as evidenced by a 62-million-year-old fossil platypus 'tooth' found in Patagonia, South America.[379] Never-the-less, they appear to be declining[380] in Melbourne's water catchments and have recently been listed as threatened ('Vulnerable') in Victoria.

Gippsland Water Dragon. © D Gordon, E Robertson CC SA 3.0 Unported.

The Gippsland Water Dragon is at home in water. © Stephen Platt.

You are most likely to first encounter a Gippsland Water Dragon (*Intellagama lesueurii howitii*) during the day when walking along a stream in far East Gippsland. It will dive from its sunny basking site on a rock or log into the river and you may hear the splash and see this accomplished swimmer crossing the water surface or diving below it. Dragons sleep on trees, branches and sometimes underwater. They live in small family groups of an adult male, several adult females and sub-adults. The diet includes plant and animal material collected in the surrounding vegetation. Up to 18 eggs are laid in a vertical burrow in a sunny spot. The sex of the young dragons is determined by the temperature in the nest during incubation. Their lifespan is up to 30 years.[381]

Imagine being born with less than a 2% chance of surviving your first year of life.[382] Spotted Tree Frogs (*Litoria spenceri*) live in the foothills of eastern Victoria in upland rivers bordered by large boulders. Their tadpoles live in the stream where they are vulnerable to predators including introduced trout, the main cause of this risky start to life.[383] This species is now restricted to a few surviving populations and is considered 'Critically Endangered'.

Spotted Tree Frog – almost extinct. © Jean-Marc Hero. CC SA 2.5 Generic.

Rocky River Frogs (*Litoria lesueuri,* also called Lesueur's Frog) shelter under boulders in gravel banks. This image shows a male and female mating (in amplexus), he being the smaller of the two. Wolf spiders and some beetles are also adapted to live on gravel banks of upland rivers.[384] © Stephen Platt.

One of several female Bronze Needle Damselflies (*Synlestes weyersii*) hangs above a stream in north east Victoria. The darker male hovers nearby chasing intruders out of his riparian territory. They will mate head-to-tail (the wheel position) for six minutes or so, then she will fly off to lay her eggs.[385] She uses a needle-sharp spine (her ovipositor) to bore a hole in the stem of a streamside rush plant and places the eggs one-by-one inside, covering them with the material she excavated. In two hours, she may complete 20 holes. The eggs will hatch and the tiny nymphs will drop into the stream where they will undergo many growth periods (instars), having to shed their external covering (exoskeleton) in order to grow. There are three feathery appendages at the nymph's tail, which are the gills. Nymphs emerge from the stream and climb a plant stem. Damselfly nymphs are slenderer than the easily-recognizable Dragonfly nymph, known as a 'mud eye' to fishers. They shed their external covering and miraculously emerge as a rapidly flying, adult insect reminiscent of a 'helicopter', thus completing their life cycle.

A female Bronze Needle Damselfly on the edge of the Buckland River in north eastern Victoria. © Stephen Platt.

Barred Skipper Butterfly (*Dispar compacta*). Kinglake. One of the 123 butterfly taxa in Victoria. © Stephen Platt.

Chapter cover: the mixed species of eucalypts seen in this image are indicative of the varied topography. Mature wattles in the foreground suggest that it has been at least 20 years since this site burnt. The relatively small trunk diameters of the gums on the far slope probably reflect the site's timber harvesting history. Broad-leaved shrubs in the understorey opposite most likely mean that we are looking northward and they are on a shaded slope facing south.

Where to see this ecosystem

Foothill forests are widespread in Victoria and within easy reach of the city of Melbourne. You will find them on either side of the Great Dividing Range. Some examples:

- Cathedral Range State Park
- Tallarook State Forest
- Lerderderg State Park
- Kinglake National Park
- Yarra Ranges National Park
- Mt Samaria State Park
- Snowy River National Park

Juvenile Tawny Frogmouths. © Stephen Platt.

Getting to know our freshwater fish

1. Murray Cod are our largest freshwater fish weighing up to 113kg. © Unknown. **2. River Blackfish are carnivorous ambush predators.** © Vanessa and Chris Ryan CC-BY-NC-Int. **3. Lower Ovens River** © Stephen Platt.

Getting to know our freshwater fish

Fish (freshwater)	Taxa	Threatened	%
Freshwater fish (native)	172	37	21
Freshwater fish (introduced)	26		

THERE ARE at least 172 taxa of native freshwater fish in Victoria (including seven that spend part of their life in the sea – diadromous) and 26 introduced species. They occur in every river and stream from coastal estuaries up to the headwaters. One in five are considered to be threatened. About 90% of Australian native freshwater fish species occur nowhere else.[386]

The challenges of being a fish are considerable. Most freshwater fish live in narrow, linear habitats that may be fast flowing or still. Others inhabit pools and wetlands that may dry up, or heat up to lethal temperatures. There is limited opportunity to avoid what flows into a wetland or down a river, such as ash and sediment following bushfires. Fish have few places to flee from predators or to lay eggs without them being eaten. They are subject to the chemistry of the water they live in, its variable oxygen content, temperature and clarity. They must maintain and adjust their buoyancy in this three-dimensional world. Food comes from the catchment, from upstream drift and attached to local rocks, snags and plants. Waterfalls and structures such as weirs and dams restrict movement upstream and the sea makes travel by water between catchments difficult, if not impossible, for most species.

Types

There is an astonishing variety of fish life forms and life strategies – lampreys, eels, herring, bream, galaxias, mudfish, grayling, rainbowfish, smelt, catfish, hardyhead, perch, cod, bass, blackfish, tupong, gudgeons and gobies. They range in size from a few grams to 113kg.

Communication

Fish use a combination of vision, chemo-sensation, and tactile cues to perceive their environment.

They communicate with each other by gesture and motion, scent, pressure waves, colour changes and some species even make sounds. Sound does not travel well from air to water and so fish are unlikely to hear what is going on in the terrestrial environment. Sounds can be made using their swim bladder (which is mainly used for buoyancy) or by knocking hard parts together such as their jaw. In order to communicate with each other, some catfish move the vertebrae in their spines to create sound.

Cox's Gudgeon *(Gobiomorphus coxii)*.

Golden Perch (*Macquaria ambigua*).

Along either flank of a fish is the lateral line system, a series of organs that can detect movement, vibration and pressure gradients in the surrounding water – good for both hunting and avoiding hunters, especially in muddy or dark water! In similar situations, catfish use their whiskers to detect prey.

Fish lack the mammalian receptors for severe pain. Based on behaviour and brain evidence, a review concluded fish are unlikely to feel pain in the same way that we do.[387]

Courtship & Breeding

Some species of fish exhibit courtship (e.g., Crimson-spotted Rainbowfish *Melanotaenia duboulayi*) and parental care. Courtship may involve colour changes and positioning.

Most freshwater fish begin life as one of a large number of eggs. For example, female Black Bream produce between one to three million eggs. Females lay their eggs before fertilization and male fish must immediately release sperm into the water to ensure their parentage.

The eggs hatch as replicas of their adult form and grow rapidly.

Fish often lay their eggs in secure places where they will be safe, oxygenated and secure. Eggs may be laid in hollow logs (Blackfish), under cobbles (Cox's Gudgeon, Macquarie Perch), in midwater (Flat-headed Galaxias *Galaxias rostratus*), attached to plants (Southern Pygmy Perch *Nannoperca australis*), be deposited in nests (Freshater Catfish *Tandanus tandanus*). Some species release their eggs directly into the water column where they will 'hide' among the free-floating plankton.

Parental care is exhibited by some species (Freshwater Catfish, Murray Hardyhead *Craterocephalus fluviatilis*, Murray Cod) but not others (Macquarie and Golden Perch).

Feeding

Food is generated both instream and within the wider catchment.

A wide range of dietary preferences occur. Large predators like Murray Cod, Golden Perch (*Macquaria ambigua*) and Trout Cod (*Maccullochella macquariensis*) feed mainly on other fish. River Blackfish eat crayfish, shrimp, fish and invertebrates. Freshwater Eels eat fish, worms, insects, crustaceans, molluscs and water plants. Murray Hardyhead feed on micro-crustaceans, aquatic insects (midge and mosquito larvae) and algae.

Fish obtain oxygen, essential for life, from the water via their gills. Loss of dissolved oxygen is often the reason for large fish kills.

Shelter

Streamside and aquatic vegetation, bank overhangs and in-stream rocks and fallen trees provide shelter from environmental extremes and predators.

Some fish will aggressively defend their territory.

Australian Bass and Silver Perch form schools as a means of 'safety in numbers' and to confuse predators.

A scaly outer body protects fish from infection and physical damage. Fish do sleep at various times but, as they have no eyelids, keep their eyes open!

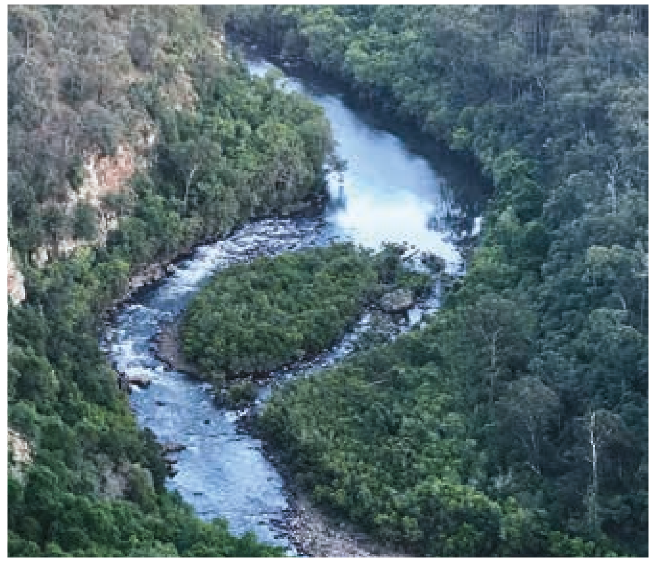
Mountain Galaxias (*Galaxias brevipinnis,* also called Climbing Galaxias) live in alpine and sub-alpine regions. During the coldest winter months, they hibernate in mud at the bottom of streams. During other months, they warm up by climbing onto rocks and bask like a lizard.

Empire Gudgeon (*Hypseleotris compressa*). © Frank Greco. CC BY 3.0.

River Blackfish (*Gadopsis marmoratus*) lay their eggs inside submerged hollow logs. © P. Jackson, J. Davies.

Climbing Galaxias. © Shiny Lizard. CC-BY-NC 4.0 (Int).

Barred Galaxias live in the headwaters of fast flowing, narrow, rocky streams and lay their eggs under cobbles. Day-old fry. © Tarmo A. Raadik[391]



Mitchell River, Gippsland. © Stephen Platt.

Movement

Some fish remain in their habitat all year round whilst others, like Australian Bass (*Percalates novemaculeata*), Murray Cod, Short and Long-finned Eels, undertake large pre-spawning migrations. These migrations may be cued by changes in water temperature, flow and daylength.

Some freshwater species move into the marine or estuarine environment at some stage of their life and must adjust their physiology to cope with the effects of salt.

Young Short-finned Eels are capable of climbing damp, vertical walls and can move across country to new waterbodies (see p 225).

The range of species in a fish community changes with altitude as those species associated with the coast drop out and cool-water-tolerant species appear.

Ecological role[388]

Fish play important roles in food-webs (trophic roles) as both predator and prey. They influence other organisms through direct competition, predation and consumption.

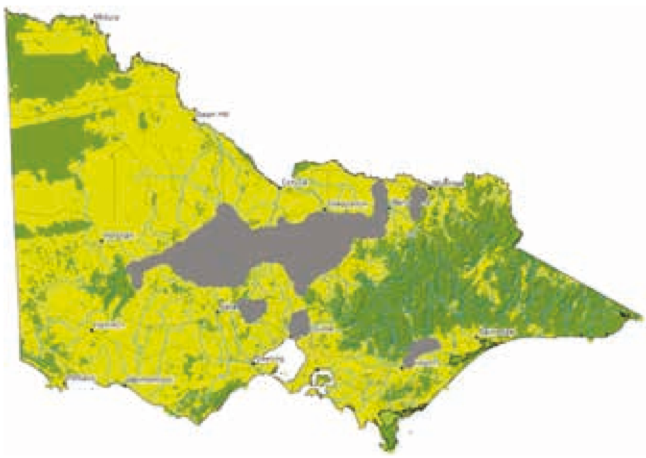
Fish help to cycle and move nutrients along watercourses in their body, through movement, excretion and death. Studies in parts of north America show that nutrients carried in the bodies of migratory salmon, which travel upstream to spawn and then die, are important for the growth of forests and the productivity of freshwater communities.[389,390]

Box-Ironbark forests and woodlands – the great honeypot

In this scene we can see the deeply furrowed bark of an ironbark eucalypt, a colony of grass trees and a small-leaved shrubby understorey. Sparse phytofall covers the ground. What does it tell us about this site?

Box-Ironbark forests and woodlands – the great honeypot

__MADE OF__ 'iron' but why? Land of honey, a place to hide under a skirt, retreating to the rocky fortress, when echidnas play trains, a spiny four-headed penis, a brush to fool predators, they bark but they're not dogs, living with ants. Ironbark and Box Woodlands pulse with life.



Approximate distribution of box and ironbark forest and woodland in Victoria.

Introduction

HOW DO we explain the bark of an ironbark? It is abundant, dark, deeply furrowed and studded with resinous, amber-like kino. You might think the bark is an ideal defence against fire but these trees are considered to be fire sensitive. Other possible explanations are that the furrows help direct rainfall toward the root zone, that retention of bark reduces the potential build-up of fire fuel at the base of the tree and that the bark ridges help shade the inner living tissues (cambium) so that they don't overheat. It may be combinations of the above or none. After all, retained bark must divide as a tree grows. No-one really knows the answer. In fact, the purpose of bark has not been widely studied. We have only just begun to unravel this and many other secrets of Box-Ironbark ecosystems.

In this ecosystem, so distinctive is the bark of the dominant eucalyptus species, the entire forest is referred to after it.

Freshly cut Red Ironbark log showing the depth and indentation of its bark. © Stephen Platt.

Iron bark is deeply-furrowed, persistent and dark with embedded granules of kino. © Stephen Platt.

Box bark is fine-grained, persistent and light-coloured. © Stephen Platt.

Ecosystem outline

Box-Ironbark Forest has a sparse understorey of small-leaved, and drought-resistant, shrubs. © Stephen Platt.

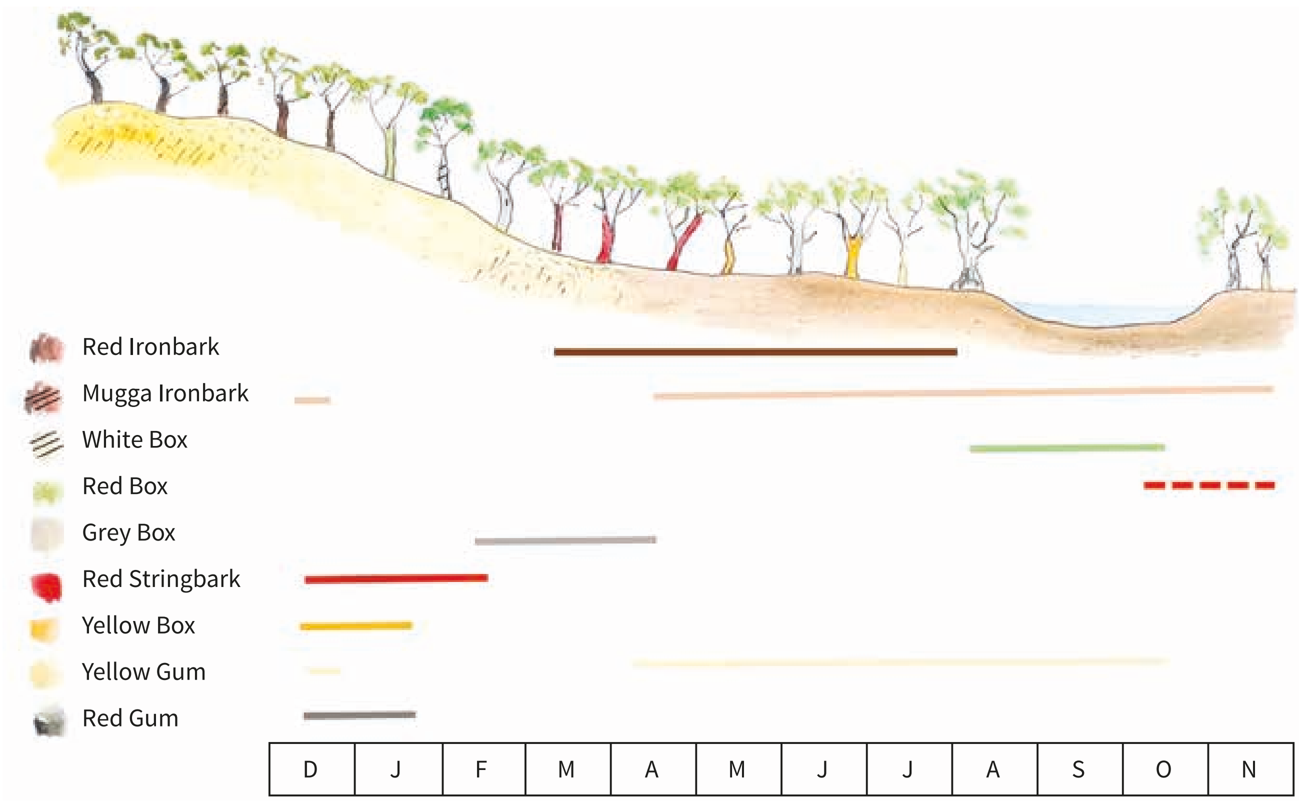
Shallow, gravelly, sedimentary soils typical of where Red Ironbark eucalypts grow. © Stephen Platt.

Why are these forests here and what makes them tick? Is their position, largely on the desert side of the low-elevation Great Dividing Range, the defining reason for their existence? Is it the ability of the dominant tree species to survive in a dry environment with poor soils and low fire risk? Or is the Box-Ironbark defined by the year-round, sequential flowering of eucalypts of many species? Maybe it is the associations between organisms that provide additional access to nutrients that defines this system? Or perhaps it's the combination of these characteristics that distinguishes Box-Ironbark from its neighbouring ecosystems.

Box and ironbark species form woodlands and open forests that grow on dry, shallow, stony, poorly-structured, infertile, sedimentary soils at low elevations. Red Ironbark is often associated with gravelly soils containing quartz fragments.[392]

This ecosystem occurs mainly on the slopes and plains inland of the Great Dividing Range where rainfall is moderate and variable, and sunlight is reliable. The forest structure is of a sparse understorey and ground layer under a canopy of moderately tall eucalypts.

Phytofall-clear zones around the base of eucalypts, and moss growth, may indicate channelling of water down the trunk toward roots in this occasionally water-starved ecosystem. © Stephen Platt.



Profile showing distribution of the main eucalyptus species and their flowering months. © Stephen Platt.

This is a highly mixed-species ecosystem of Yellow Box, Red Box, Grey Box, White Box, Red Ironbark, Mugga Ironbark, Red Stringybark, Yellow Gum and Red Gum. Whilst there is considerable overlap in distribution, there is also a clear progression from Red Gum at the lowest elevations to Red Ironbark at the highest and driest elevations. Despite the relatively low topography it, along with soil depth and variations in nutrient and water status, has enough influence to provide a range of opportunities for different species to co-exist.

If we compare this ecosystem with the mixed species forests on the southern side of the ranges, rainfall in the Box-Ironbark is lower and more variable and the species more drought resistant. We can imagine the pulse of the central Australian deserts expanding during droughts to influence this north-facing side of the Great Divide. In summer, hot, dry north-westerly winds place further stress on this ecosystem. Here we are well away from the influence of the sea, unlike south of the Divide.

Peas and wattles are common in the understorey. They compensate for low soil nitrogen through an association with nitrogen-fixing bacteria that form nodules on their roots.
© Stephen Platt.

Nectar and pollen from flowering eucalypts provide much of the energy that sustains wildlife in this system. The main winter-flowering *Eucalyptus* species – Red Ironbark (*E. tricarpa*) and Yellow Gum (*E. leucoxylon*) – have big, robust, pendulous flowers and seem to have evolved for bird pollination. The summer-flowering species – Yellow Box (*E. melliodora*) and River Red Gum (*E. camaldulensis*) – have smaller, upright flowers more suited to insect pollination. Flowering tends to be earlier in warmer sites.

We can think of nectar as a resource that fluctuates in availability at the landscape, patch and site scale. From the perspective of wildlife, there are 'good' and 'not so good' years.

Total floral nectar resources vary between years due to rainfall variability and are patchily distributed across the forest. Hence, wildlife with an ability to move around has an advantage in locating this food resource.

The amount of nectar available in winter is sufficient to transform the resident bird communities as mobile species like lorikeets, with their brush-tipped tongues, and other honeyeaters arrive to feast. But winters are not always the same. In drought years large areas of forest may fail to flower whilst in wet years most trees will flower.

Large trees provide more total nectar and a more reliable supply every year: big trees – big canopies – more space for more flowers and a root system that has access to more reliable water and nutrients.

Big trees are particularly important in sustaining wildlife in years of below average flowering.[393,394,395,396] They tend to be found in drainage lines where Eastern Ring-tailed and Common Brush-tailed Possums, and Yellow-footed Antechinus are more abundant.[397] Only very large, old trees provide abundant hollows used by wildlife. About 42% of trees over 60cm diameter at breast height are hollow-bearing. Only 0.4% of trees are in this category but they account for one third of canopy hollows. Red, Yellow and Grey Box (*E. macrocarpa*) have a greater number of hollows than other eucalypt species, even in larger tree sizes.[398] Loss of large trees during the 1850s gold rush era has created a problem for wildlife in this ecosystem especially through loss of nectar and hollows. Species such as Turquoise Parrots (*Neophema pulchella*) and Yellow-footed Antechinus (*Antechinus flavipes*) sometimes resort to hollows created in the stumps of previously felled trees.

Sundews (*Drosera* sp.) obtain nitrogen by capturing and consuming small insects that get trapped on sticky 'hairs'. © Stephen Platt.

Red Ironbark flowers produce abundant nectar that attracts birds. © Stephen Platt.

Musk Lorikeets (*Glossopsitta concinna*) are highly mobile and have brush-tipped tongues and small beaks adapted for sipping nectar. © Stephen Platt.

Noisy Friarbird (*Philemon corniculatus*).

The lack of a dense shrub understorey in Box-Ironbark Forest means that fire is typically of low intensity. © Andrew Bennett.

It is argued by some authors that the reason for the large number of big honeyeaters in this and similar systems is a result of plentiful sunshine and nutrient-poor soils. Plants use photosynthesis, which is powered by sunlight, to grow. Photosynthesis also requires water, and nutrients in specific quantities. However, our ancient soils lack some essential elements required for plant growth, such as phosphorus and zinc. To get enough of these elements, eucalypts 'over-produce' other products of photosynthesis, particularly sugars, creating an oversupply. The plants convert this excess-to-their-need sugar supply into nectar to attract bird pollinators. The quantities of nectar are sufficient to be worth defending. To do this, birds create territories centred on their food source and attack intruders. Bigger birds (e.g., wattlebirds, friarbirds) and colonial birds (e.g., Noisy Miner *Manorina melanocephala*) can do this more effectively than single, small birds. But the birds also need critical nutrients not supplied in nectar. They get them by consuming invertebrates. For example, wattlebirds will chase down tiny insects, hardly worth the effort, not for their energy content but to obtain the critical nutrients they contain.[399,400] Hence, we see a eucalypt forest on poor soils, producing lots of nectar, with a canopy being patrolled by large, aggressive honeyeaters.

Due to the dryness and relatively slow accumulation of fuels in most areas, fire is not as significant an influence here as in the wetter forests. It takes many years for significant phytofall, that could sustain a fire, to accumulate. Fires do occur but they tend to be less intense than in wetter ecosystems. Low severity fires occur on average around every 12 years and high severity fires every 30 to 150 years.[401]

Peas and wattles (*Pultenaea* spp. and *Acacia* spp.) are common understorey species in these forests. Both only reproduce by seed after fire (are obligate seeders). They do not reshoot.

Some understorey species disperse their seeds by explosive force. On a hot summer day, acacia pods split and curl throwing the seeds about. This behaviour explains the often-contorted shape of *Acacia* seed pods. The seeds can lie dormant in the soil until fire breaks the seed coat allowing water to penetrate and initiate germination. The risk of the fire interval exceeding the time that seed remains viable in the soil may be offset by a small proportion of seeds becoming non-dormant without fire (i.e., germinating without a fire occurring), as has been found for some wattles.[402]

Scarlett Robin (*Petroica boodang*). © Deborod CC BY-NC 4.0 (Int).

Browse line on a Cherry Ballart (*Exocarpos cupressiformis*) at Heathcote indicates a high density of kangaroos. © Stephen Platt.

Moth cocoon wedged into the lattice-like bark of an ironbark. © Stephen Platt.

Cryptogamic mats of soil-encrusting lichens, mosses, liverworts and ferns sustain soil health and provide a moist space for seed germination. © Stephen Platt.

In Box-Ironbark ecosystems, animals are less likely to be killed by bushfire. Studies indicate that they do not vacate the forest after bushfire. For example, following an experimental planned burn in which flames did not scorch the tree canopy, Scarlet Robins remained within their burnt territory but expanded its size threefold. Yellow-footed Antechinus and Brush-tailed Phascogale survived the fire but would have been affected by the loss of phytofall, including logs, and of dead hollow-bearing trees resulting in loss of food and shelter.[403] Of 52 Antechinus den sites, one third were completely burned by the cool, patchy burn.[404] These experiments suggest that with a relatively low severity fire, wildlife can usually survive and remain resident in these forests, though the wildlife is far from unaffected.

The tight-fitting bark of the dominant eucalypts means that there are fewer under-bark invertebrates in the Box and Ironbark eucalypt component of these forests. However, soil, on-bark and aerial invertebrates are at times abundant.

Plant life

RED IRONBARK (*Eucalyptus tricarpa*) is a slow-growing, medium-sized (25–25m) tree with dense wood and thick, dark, furrowed bark covering the trunk and branches. The bark is impregnated with kino deposits. Eucalyptus kino was used by aborigines in a tea for treating colds. *Tri carpa* means 'three fruit', and it is a characteristic of this species for flowers to be arranged in bundles of three. The dense wood is prized for many uses, a characteristic that led to widespread timber harvesting during the 1850s gold rush era and beyond.

Golden yellow is a common colour in the understorey of Box-Ironbark forests during winter and spring. Both wattles and peas display this colour. But why yellow? Flies, in particular, are attracted to yellow-green flower colours and are important as pollinators.[405] This may explain the colour of wattles. On the other hand, many peas also have red colouration. They are preferred by native bees that can see the pea flower's enticing ultraviolet markings. Do we owe flies and bees our gratitude for this magnificent winter-spring floral display? It seems that we do.

If you look carefully at the leaf-edge of the late winter-early spring flowering Golden Wattle (*Acacia pycnantha*) you will see a small gland (extrafloral nectary). It produces nectar that attracts honeyeater birds and invertebrate pollinators including ants, flies and bees.[406] Oddly, in this species and unlike in most other flowering plants, pollen and nectar sources are separated spatially.

A massive Ironbark in the Brisbane Ranges with numerous hollows, unlike younger individuals. Person at base indicated. © Stephen Platt.

Golden Wattle nectaries and pollen attract a range of birds and invertebrates, including this hoverfly. The 'leaves' of wattles are actually flattened leaf stalks (phyllodes) with a gland offering nectar on their margin. © Stephen Platt.

Wood-boring beetle grub inside a Golden Wattle. These grubs are sought after by large cockatoos that rip the wood apart to expose and eat them. © Stephen Platt.

The wood of Golden Wattle is food for several species of jewel beetle (*Agrilus assimilis*, *A. australasiae* and *A. hypoleucus*) and the leaves food for butterfly caterpillars (Fiery Jewel, Icilius Blue, Lithocroa Blue and Wattle Blue).

Wasps (*Trichilogaster* sp.) initiate galls in the flowerheads and a rust fungus (*Uromycladium tepperianum*) is responsible for black to brown crusty galls on the stems.

Golden Wattle is reasonably short-lived (15–30 years) but survives as hard-coated seeds in the soil seed bank. Fire may kill the above-ground, parent plant but Golden Wattle can resprout from its rootstock and re-establish from seeds which germinate *en masse* post fire.

The larvae of *Agrilus hypoleucus* feed on the wood of Golden Wattle. © Alan Melville, CC-BY-NC-ND 4.0 (Int).

Wattle Tick Scale (*Cryptes baccatus*) on a Golden Wattle stem.
© Stephen Platt

Grass tree following a fire. Note that the original dense leaf 'skirt' is missing, a new one with singed leaf tips from the fire is forming, the trunk is blackened and a flower spike, initiated in response to the fire, is in full bloom. The flowers will provide much needed resources to animals including Sugar Gliders, butterflies and other invertebrates. The skirt will re-establish and provide shelter to other species. © Stephen Platt.

Grass trees are unique to Australia and occur in Box-Ironbark forests and in other seasonally dry forests and woodlands as scattered colonies. They can reach a mighty age of hundreds of years.[407] In their unburnt state, the leaves of former years hang down to form a skirt around the trunk. This creates a great place for wildlife to hide and shelter.

Synchronous flowering of grass trees after fire. The flower spike, which may be two metres tall, attracts butterflies, moths, Sugar Gliders and many other species. Wilson's Promontory 2009. © Stephen Platt.

Grass tree leaf skirts provide shelter and security to a wide range of animals. In this case a bird has nested under the skirt.
© Stephen Platt.

Despite their age and height, Grass Trees have small root systems. © Stephen Platt.

Juvenile grass trees (in the foreground) may be 60 years old before they start to produce a trunk. In Heathcote-Graytown N.P., grass tree colonies are often in open heathy areas where trees struggle to survive. © Stephen Platt.

To reach their potential lifespan, grass trees have to survive numerous fires. Young grass trees do this by having a growing tip that is 12–23cm below the soil surface. After germination, contractile fibres in the roots pull the growing tip down about 1cm per year until stopped by a solid object like a rock.[408] They remain at this stage, with leaves poking out of the soil surface, for decades (50–65 years for *X. glauca subsp. angustifolia,* which grows in Victoria inland of the Great Divide). Subsequently, they develop a trunk. The trunk's growing tip is protected from fire by moisture held in the tightly-packed leaf bases surrounding it.[409]

A tunnel (arrowed) has been made into the skirt of these grass trees. © Stephen Platt.

Resin which coats the leaf bases that form the 'trunk' (cordex) of a grass tree also form lumps at the base. Grass tree resin was used by Aborigines, after heating, as a malleable 'glue' for attaching spear heads. Europeans considered using the resin to produce explosives. © Stephen Platt.

The trunk itself is made of leaf bases coated in a resin and usually does not burn long enough for the grass tree to die. Natural mortality, without fire, is about 9% over a century.[410] Thus, most grass trees survive fire and respond to the opportunity it presents to flower, set seed and regenerate in the open space created by the fire.

In New South Wales, 3,000 individual *Xanthorrhoea resinosa* plants were followed for 23 years. This species, which grows in Gippsland coastal heathland, is likely to require 40–160 years to reach maturity and 120–240 years before there is significant reproductive output. It was found that some populations were declining and predicted to go extinct within 200 years. Death due to post-fire heat shock, the effort of flowering post fire and longer-term competition with shrubs such as Banksia, which can deny grasstrees sufficient sunlight, is suggested as the cause of the predicted localised extinction of the studied population.[411]

Fire scars can cause grass trees to lean and eventually snap in half causing death.

Some species are cued to flower after fire (*X. australis*) whilst others flower continuously (*X. glauca ssp angustifolia*).

Hence, fire is a double-edged sword – needed to retain forest health but not too often or too hot, and must be seen in the context of competition from other species.

In some grass tree species, fire history can be determined by looking at the pattern of cream and brown leaf bases along the trunk interspersed with black ones signalling a fire.[412] The long-term history of fire recorded in the leaf bases has been used to understand Aboriginal use of fire before European settlement of Australia.

Aboriginal people made extensive use of grass trees. They ate the roots, dipped the flowers into water for a sweet drink, made fire using the flower stem and a hardwood drill, used flower stems as spear shafts, and used the resin as heat sensitive glue for binding axe and spear heads to a wooden shaft and also to patch water containers and watercraft. I wonder whether Aboriginal children also formed the resin into toys, as my children have done?

Just outside the Box-Ironbark, in the hills in north-eastern Victoria, such as near Mt Pilot, Chiltern and Beechworth, Black Cypress Pine (*Callitris endlicheri*) grows on rocky, granitic hills. They are non-flowering plants, unlike the gums (Red Stringbark *E. macrorhyncha*, Long-leaved Box *E. goniocalyx* and Red Box *E. polyanthemos*) that share this environment. Cypress Pine's existence and extent is determined by the interplay of fire, competition with eucalypts and the terrain. It's a life and death dance.

In coastal areas, but not in Box-Ironbark, banksias compete with grass trees and, without a fire, may overshadow and kill them. © Stephen Platt.

The full skirts of brown leaves indicate that this site, and these grass trees, have not been burnt for decades. Their height indicates great age. © Stephen Platt.

The skirt on this grass tree has been browsed (at the point of the arrow). © Stephen Platt.

Black Cypress Pine at Beechworth.[413] © Stephen Platt.

Black Cypress Pines are fire sensitive and usually killed by fire. However, in the rockiest locations they tend to remain unburnt as fire cannot reach them. You will notice the largest specimens among the large boulders. These sites provide core populations, safe from fire. Without fire, over time the pines expand out from these core sites into the surrounding area. When fire occurs, those without the protection that rocks provide will be killed. Thus, there is an ebb and flow of pines expanding and contracting from their rocky fortresses in concert with fire history. This cycle takes many years.[414]

When fire affects this community, thousands of seedlings of both pine and eucalyptus germinate, the juvenile eucalypts growing at a much faster rate than the long-lived pines. In a case of 'the tortoise versus the hare', the eucalypts initially race skyward ahead of the pines. Growing slowly underneath them, the pines gradually form a dense understorey that monopolises water. This prevents germination of eucalypt seedlings. They can maintain this density because cypress-pines are among the most drought-tolerant species on Earth. Once the eucalypts mature and die the site will likely revert to pines, that is unless there is another fire!

Animal life

With all males dying annually, Brush-tailed Phascogales live a precarious existence. © Ern Mainka.

THE TUAN or Brush-tailed Phascogale (*Phascogale tapoatafa*) is a rat-sized marsupial (has a pouch) with a dark brushy tail the size of its body. But why the oversized, hairy tail? Tuans are preyed on by owls. An owl swooping down to grab a Tuan may mistake its tail for its body allowing the Tuan to make its escape. Ingenious! Other anti-predator behaviours of Tuans include hissing, biting, spiralling up trees as they make their escape and foot tapping. The latter occurs after the Tuan has found a safe position and may signal as much to its predator.[415]

In the breeding season, males can make large migrations of over 15km, looking for females.

Like many of our small mammals, including all antechinus species, Tuans have an extra ordinarily precarious life cycle. They essentially mate to death. So much energy is used up in the mating ritual that all males die at the end of each season, thus living for just one year. They are the largest mammal with this life history. Females give birth to, and nurture, an average of seven young. Only a third of females will survive to breed a second time.[416] The next generation is literally made up of new, young individuals. The young remain attached to their mother's teats until about seven weeks old. Then, weighing just two to four grams, they are left behind in a hollow and covered with fur or feathers for warmth while she forages. After 150 days the young will leave the nest for an independent life.

Tuan habitat preference is typically a dry, lightly-treed ridge on a hill, often with little or no understorey and a few large, hollow-bearing trees for dens. They move between dens in order to avoid attracting predators and to reduce parasites. Tuans eat large invertebrates, including spiders and centipedes, and nectar when it is available.

Yellow-footed Antechinus. © Russell Jones.

A pile of small droppings spilling from a hollow at the base of a large tree or glimpse of a mouse-sized animal running along a fallen log might alert you to the Yellow-footed Antechinus (*Antechinus flavipes*).

The small, ground-dwelling Yellow-footed Antechinus is the most abundant mammal on the forest floor and, though mainly active at night, is often seen during daylight hours. It searches for its mainly invertebrate prey on fallen timber and in trees (scansorial). It is also one of numerous mammals that consume underground (hypogeal) fungi (i.e., truffles).[417]

Yellow-footed Antechinus den at the base of a Yellow Box with droppings spilling from the entrance. © Stephen Platt.

They prefer habitat with a large quantity of ground-covering leaves, twigs and branches as well as hollow-bearing trees and rocks[418] located in moister parts of the landscape. Antechinus use cavities in trees and fallen logs as dens. An average of over six den sites are used by each animal. Larger trees and logs are preferred. Fallen branches and logs provide protection and pathways to escape potential predators. The cover of leaves, twigs and branches on the forest floor has the greatest influence on whether Yellow-footed Antechinus will be present at a site[419]. Phytofall harbours their invertebrate prey. Rock cover is also important. Yellow-footed Antechinus populations increase after floods, corresponding with a spike in their invertebrate prey.

Unfortunately, years of mining, firewood collection and forestry have reduced fallen timber to less than one fifth of the original, pre-European quantity.[420]

Like all antechinus and the Brush-tailed Phascogale, following an exhausting mating ritual (copulation can last five hours)[421] during the July breeding season, all males die within days of each other leaving the females and dependent young behind.[422] The females will raise the young alone in a nest, which is usually a tree cavity but logs, stumps and grass trees are also used. They will also die after perhaps surviving to a second season. The new young make up a new population and the precarious cycle continues. No need to get on with your parents here! Clearly, it is a successful strategy as there can be no break in the long chain of annual breeding success without population extinction.

A period of good rainfall leads to population increase, whilst drought causes a collapse in numbers.[423]

All species of Antechinus and Phascogale have a precarious, short-lived life-cycle connected to an unpredictable environment. Male Antechinus live for just one breeding season. © Stephen Platt.

Despite a very focussed diet largely of ants and termites, Short-beaked Echidna's and their ancestors have successfully navigated massive environmental changes since the break-up of Gondwana. Note the front and rear feet claws for digging. © Alison Milton CC-BY.

Short-beaked Echidna excavations in an ant nest. © Stephen Platt.

A baby echidna or 'puggle' lacks the spines that would make suckling milk from its mother's chest difficult for her. © Steve Parish.

If you let your imagination run wild, perhaps you can understand why Australia's spiny anteater, the Short-beaked Echidna (*Tachyglossus aculeatus)*, was named after *Echidna* of Greek mythology being half woman, half snake. Or, perhaps not. They have the fur of mammals and lay eggs like a reptile. In this respect monotremes, like the Echidna, remind us of the evolutionary link between ourselves as mammals and an ancient reptilian ancestor.

Found in a wide range of habitats, you may notice their excavations, made with powerfully-clawed feet, and deep, beak-holes in ant and termite nests.

Typically, Short-beaked Echidnas are encountered individually, waddling about the bush and, when startled, rapidly digging-in to protect their soft underbelly and expose a phalanx of spines. But how do we explain echidna 'trains' where up to ten individuals follow one another in a line?

Short-beaked Echidnas have nine sex chromosomes (humans have two – an XY system)[424], and a seven cm long, four-headed, spiny penis (well how else to get past all those spines?). When ready to mate, males seek out females that emit a strong-smelling scent, and a 'train' of amorous males, with the youngest last in line, may follow her seeking an opportunity to mate. The train may last for weeks. Eventually she signals her readiness to mate and the males participate in a kind of trench warfare, head butting each other out of a trench they make around her, until one dominates.

Short-beaked Echidna 'train'. © Janet Page CC NY 4.0

A leathery-shelled egg is laid directly into the females' pouch. The young, spineless Echidna, weighing half a gram, escapes the egg using a reptile-like egg tooth. Suckling on milk excreted from skin within the pouch, within ten days it will increase in weight 30 times. As spines develop, the young are left in a nursery burrow until they wean at seven to nine months. The Short-beaked Echidna's body temperature is relatively low (32^0C) and fluctuates during the day so in extreme hot or cold weather they seek shelter under a rock or in a log. They live a long time – perhaps 45 years in the wild.[425]

Barking Owls live in the dryer forests. Their call, heard at night, sounds like the bark of a distant dog. © Mat Gilfedder.

You may come upon a dry pellet on the forest floor comprised of fur, feather and bone fragments the size of a golf ball. As for other owls and eagles, these balls of inedible materials are coughed up (regurgitated) after eating as a pellet of waste by Barking Owls (*Ninnox connivens*). If you find one, look up because you may be standing beneath a roost tree.

Barking Owls have large home ranges of around 1,400ha.[426] From their nest tree, a pair of owls will concentrate their foraging activity in areas with a high abundance of prey. They eat mammals such as Sugar Glider, roosting birds (to the size of a magpie), bats, rodents and insects. Drought and fire can halve the population in an area. Although owls can usually flee the flames, their prey may not and thus they starve following the fire. Barking Owls mate for life and rely on large hollows (>20 cm entrance diameter) for shelter and breeding. Areas near water, where prey abundance and large trees with hollows coincide, are often chosen. They lay two to three white eggs on the rotten wood at the base of a hollow, which aids drainage. Young owls may be seen in spring sitting on a limb outside their nest. Of a night, listen for the characteristic double 'hoot' barking sound or, occasionally, a high pitched, scary scream of the adults, or the young repeatedly begging to be fed.

All records of the Pink-tailed Worm-Lizard (*Aprasia parapulchella*) come from the Box-Ironbark ecosystem near Bendigo. It primarily eats the eggs of small ants.
© Damian Michael CC-BY.

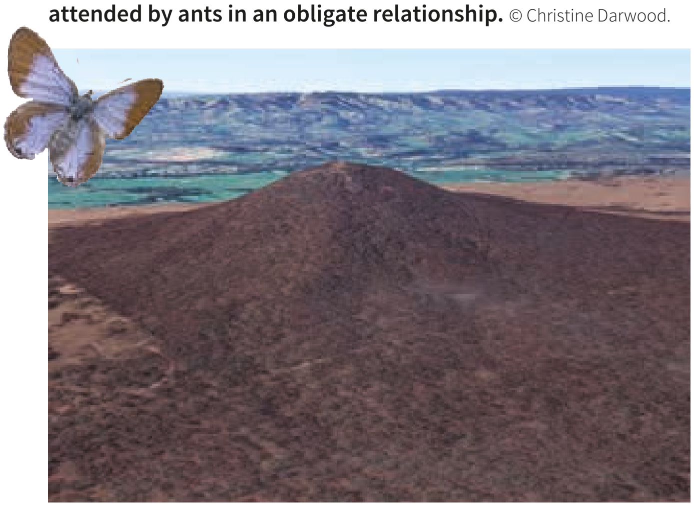
Phytofall (fallen leaves, twigs and branches) is significant in these forests as it harbours a diverse range of invertebrates that are prey to other animals. Most are small. Around one third belong to the family containing sawflies, wasps, bees, and ants (Hymenoptera). Their abundance varies seasonally, with more around when moisture is available in spring and least in the dryness of summer.[427]

The ground-dwelling invertebrate fauna in Box-Ironbark forests is dominated by ants and wasps (59%), beetles (22%), flies (7%) and bugs (4%). At least 220 species of ants and 33 families of spiders have been recorded.[428]

Consider this lifestyle – you emerge from an egg laid near an ant nest. Not just any ant, it must be a Coconut Ant (*Papyrius nitidus*). On hatching, the ants carry you to their nest in fallen timber, a stump or a standing tree. With the help of the ants, you are herded down into the caverns of their nest where you will eat the ant larvae (myrmecophagy). In return, you will exude fluids that supply carbohydrates and amino acids to the ants. Sometimes you will venture out of the nest at night. After growing, you will gather with other caterpillars and pupate. In summer, once you emerge from your underground cocoon as a small butterfly, you make your way to a hill top, probably one that has been used ancestrally for many generations (this is called 'hill-topping' and is observed in a range of invertebrates). Here, among the tree tops you will find a mate and return to lay eggs in the surrounding landscape near to some Coconut Ants.[429, 430] This is the extraordinary life of the critically endangered Small Ant-blue Butterfly (*Acrodipsas myrmecophilia*).

The Coconut Ants also need to forage in shrubs, such as wattles and trees for honeydew produced by sap-sucking bugs (Hymenoptera). These shrubs are affected by any fires. Ant nests have been found in long-unburnt areas. Hence the fire regime and whether it supports shrubs, bugs and ants plays an important role in this butterflies' survival.[431] The open forests and woodlands in which this butterfly occurs have been extensively cleared for agriculture.

1. The Small Ant-blue Butterfly (female shown, 20mm across) is listed as Critically Endangered in Victoria. © Christine Darwood. **2. Small Ant-blue Butterfly egg (~0.5mm across). Mt Piper.** © Ken Walker. CC-BY-NC-SA 4.0 (Int).**3. Caterpillars and 4. Pupae are attended by ants in an obligate relationship.** © Christine Darwood.



Aerial view of Mt Piper, near Broadford, (looking east) a butterfly hill-topping site. Source: Google Earth.

Male Red-headed Mouse Spider. © Juliet Lowther.

Tap, tap, tap – the male Red-headed Mouse Spider (*Missulena occatoria*) knocks on the oval-shaped, trap-door entrance to the burrow (up to 30cm deep) of a female. She is much larger, all black and remains sluggishly in or near her burrow for life. He reaches sexual maturity at four years of age and probably tracks her scent (pheromones) as he moves around to find her. If he is let in, they will mate and she will lay 60 or more eggs in an egg sac which will be kept in a side chamber to the burrow. It is also where the spiderlings will live until they disperse by ballooning away on their own silken parachutes. These spiders eat insects and other spiders and occasionally small frogs and lizards. They in turn are preyed on by parasitic wasps, scorpions, centipedes and bandicoots. The female produces a strong toxin that can be harmful to humans, though we are unlikely to ever encounter her.

Two-tailed Spider (*Hersiliidae*) egg sac. © Stephen Platt.

Meat Ants (also called Gravel Ant, *Iridomyrmex purpureus*) are omnivores and forage during the day. The sticks and stones they deposit on a mound outside the colony entrance may act as a heat sink. Workers undertake ritualised fighting at the territorial boundary with adjacent colonies.[432] © Stephen Platt.

In conclusion, Victoria's Box-Ironbark forests and woodlands are adapted to survive occasional extreme moisture stress on soils of low fertility. They are occupied by animals that are attracted to their abundant nectar resources and relative fire safety. These critical nectar resources are subject to the unpredictable variability in climate.

Chapter cover: In this scene we can see numerous tall grass trees. A reasonable estimate is that they are some 200–300 years of age. Their leaf skirts are intact indicating that there has not been a fire for many years. This is also supported by the absence of wattles and peas with relatively short, post-fire lifespans (e.g., Golden Wattle). The small-leaved shrubs and sparse phytofall indicate that this is a dry environment where water conservation is significant and fire is of low intensity. The ironbark is of a reasonably large diameter but probably does not pre-date the mining era when these landscapes were stripped of timber.

Historical note

Alluvial gold was discovered on the banks of the Bendigo Creek in 1851. The ensuing goldrush dramatically altered the landscape occupied by Box-Ironbark ecosystems. Timber was used for heating, shoring up mine shafts and many other uses. Unprotected soils washed downslope leaving ridgelines depauperate. Despite this, Box-Ironbark ecosystems have survived and are now recognised for their unique qualities and protected.

Where to see this ecosystem

Box-Ironbark Forest occurs primarily inland of the Great Dividing Range between Wodonga and Horsham.

- Greater Bendigo National Park
- Heathcote-Graytown N.P.
- Castlemaine Diggings National Heritage Park
- Kooyoora State Park
- Deep Lead Flora and Fauna Reserve
- Chiltern-Rushworth National Park.

Getting to know our birds

1. Pink-eared Duck. © Juliet Lowther. **2. Superb Parrot.** © Ron Knight. CC 2.0 Generic. CC-BY-NC 4.0 (Int).
3. Fan-tailed Cuckoo. © Juliet Lowther. **4. Hooded Robin.** © Juliet Lowther.
5. Diamond Firetail. © Michael Haines. CC-BY, **6. Brown Thornbill** © Juliet Lowther
7. Wedge-tailed Eagle © Regnans CC-BY-NC 4.0 (Int).

Getting to know our birds

THERE ARE some 523 taxa of native birds recorded in Victoria of which 104 taxa are threatened – or one in every five species.[433]

Birds	Taxa	Threatened	%
Birds (native passerine)	171	18	11
Birds (non-passerine)	191	44	23
Birds (waders)	75	21	28
Birds (marine)	86	9	10
Birds (introduced)	26	–	
Total (native birds)	523	92	18

Types

Our birds are incredibly diverse – there are at least 95 families of birds in Australia. They include marine, coastal, freshwater and land birds. A major division is between perching birds (passerines) and those that are not perching (non-passerines). There are birds that no longer fly (e.g., Emu), that swim in the sea (e.g., penguins) and that migrate thousands of kilometres to breed (e.g., Far Eastern Curlew). Some prey on other birds (e.g., Peregrine Falcon). Our understanding of the relationships between birds and their classification is still developing.[434]

Birds have adapted to every habitat in Australia, from desert landscapes to rainforests and alpine areas.

Communication

Birds are unable to show facial expressions, such as smiling in humans, but have evolved other means of communication through song, dance, colour and movement. Not many other animals sing!

Birds are very vocal. The earliest known songbird fossil comes from Murgon in south east Queensland. It is another 20 million years before fossils of songbirds appear outside Australia. Could Australia have been the centre of evolution of the songbirds, the most abundant group of birds? Genetic evidence supports this idea. Songbirds probably dispersed from Australia when the continent became connected via the Indonesian Islands to other parts of the world.[435, 436]

Birdsong serves many functions including advertising for mates, social cohesion and defence of a territory. Around 30% of birds sing at night. Willie Wagtail (*Rhipidura leucophrys*) males sing at night during the breeding season and this increases with the fullness of the moon.[437] The 'dawn chorus' is indicative of how many species of birds are territorial, their song serving to remind competitors of territorial claims in this glorious way.

A few birds – chough, apostlebird, magpie – engage in play. White-winged Choughs (*Corcorax melanorhamphos*) are clever enough to use tools and will hit mussels with old shells to open them.[438]

Whilst many complex animal behaviours are genetically coded and instinctive, some birds, such as Sulphur-crested Cockatoos, are able to learn novel behaviours, such as garbage bin opening, and pass them on to others culturally.[439]

Feeding

Birds are adapted to eat plants, seafoods, freshwater algae, seeds and fruits, nectar, invertebrates and their products, meat and carrion. It's a very wide range but most are specialists in one or few of these food types. Bird diets must include the full range of nutrients their bodies require.

Their body shapes, and particularly their beaks, are designed for the foods they specialise in feeding on. Spoonbills wave their bill from side to side imitating the action of an aircraft wing. A difference in water pressure created by the bill shape creates a vacuum that sucks in the tiny freshwater organisms on which they feed. The curved, sharply-pointed beak of a White-winged Chough is ideal for flipping leaves and digging soil as it hunts for prey. Oystercatchers have very long beaks for probing into intertidal mud in search of worms. Rainbow Lorikeets have brush-tipped tongues for lapping up nectar.

The Common Bronzewing Pigeon (*Phaps chalcoptera*) feeds on the ground eating seeds, leaves and invertebrates.

A Yellow-tailed Black-Cockatoo (*Calyptorhynchus funereus*) looking very pleased after excavating a large grub from the adjacent wattle. Look carefully and you will notice how common these excavations are in the bush. This parrots powerful beak is suited to breaking open the fire-adapted, woody fruits of *Banksia*, *Hakea* and *Allocasuarina* to obtain the nutritious seeds they contain. © Stephen Platt.

Red-capped Robins pounce on their prey from a perch. They often feed with other small insectivorous birds such as thornbills. A very widely distributed bird.
© David Tytherleigh, CC-BY-NC 4.0 (Int).

White-winged Chough. Choughs are one of many species of mud-nesters. © Ronigreer. CC-BY-NC 4.0 (Int).

Fairy Martin (*Petrochelidon ariel)* mud nests beneath a granite boulder overhang. © Stephen Platt.

In 1977, David Paton discovered that honeyeaters collect manna, honeydew and lerps off the bark and foliage of eucalypts, and not insects as had been previously thought. 'Manna' is a white substance high in sugars produced by eucalypts, especially Manna Gum (*E. viminalis)*. A lerp is the sugary tent-like covering built by an insect called a psyllid. Honeydew is a liquid produced by sap-sucking bugs and is also high in sugars. You will find these bugs on fine stems of plants or under bark. The honeyeaters obtain carbohydrates from these non-nectar sources. As Tim Lowe, author of 'Where song began' eloquently explains – "Lerp and honeydew exist because there is far more sugar in tree sap than amino acids, forcing sap-suckers to imbibe more sugar than they need so as to meet their protein needs. Excess sap flows from their rectum as sweet liquid, or is sculpted into lerp 'palaces'.[440,441] Lerps are eaten by most foliage birds and some, such as the Bell Miner, harvest the lerp covering leaving the psyllid insect that built it to make another, thus 'farming' their provider. Occasionally psyllid infestations are sufficient for human harvesting and Aborigines would strip leaves to obtain this sweet food.

Sugary lerps (white 'tents') hide their psyllid creators that suck sap from leaves. They are attended by ants that offer protection in exchange for sweet secretions. © Stephen Platt.

Southern Boobook (*Ninox boobook*), also known as a 'mopoke' due to its frequently-heard, two-syllable mo…poke call occupies all treed environments. © Chris Charles CC-BY.

A female Spotted Pardalote (*Pardalotus punctatus*) with two lerps in its beak, which is designed for prizing them off. © Ákos Lumnitzer.

This Eastern Spinebill (*Acanthorhynchus tenuirostris*), though a 'honeyeater' is about to consume an insect, needed as a source of protein. © Juliet Lowther.

Courting male Musk Ducks draw attention with loud whistles. © Deb Taylor CC-BY-NC 4.0 (Int)

Galahs wave a sprig of leaves in courtship. © Stephen Platt.

Male Satin Bowerbirds practice elaborate courtship displays in their rainforest habitat. A woven bower is adorned with irresistibly attractive blue objects and is the arena for his dance, all to impress the female. It is not a nest, which is placed in a much safer location. © Judd Patterson. CC BY-NC 4.0 (Int).

Courtship

Elaborate courtship displays are common in birds. Male Musk Ducks (*Biziura lobata*) extend their throat sac, hold their head and tail erect, splash jets of water behind and whistle, plonk and whump loudly.

Male Satin Bowerbirds (*Ptilonorhynchus violaceus*) create an ornate bower of matted grass filled with attractive objects in order to attract a mate. Superb Lyrebirds mimic forest sounds and elaborately display on a mound. Galahs (*Eolophus roseicapilla*) snip off a sprig of gum leaves and wave it around outside the breeding hollow.

Counterpoint to these displays of love is the need for camouflage from predators. Most females, but not all, have dull plumage that conceals their whereabouts whilst sitting on eggs. However, in the case of the female Plains Wanderer, a small bird that spends most of the time on the ground in grasslands searching for seeds, she is the colourful one, her dull-plumaged mate, being tasked with sitting on the eggs, is camouflaged in grass-coloured plumage (see p 110).

This male Spotted Pardalote, resplendent in his brilliant yellow plumage, raises his crest as he courts the female. © Stephen Platt.

Breeding

Birds have a unique problem. Their bodies are too warm for the proper development of an egg. Thus, the egg is deposited out of the body. In the atmosphere, temperatures range widely. So, birds must incubate their eggs, keeping them warm when needed and cooler when at risk of overheating. Most birds do this by sitting on a nest of eggs but a few species have another approach – they build a mound that includes rotting vegetation and place their eggs inside. Heat is produced by the vegetation and it keeps the eggs warm. The parent bird adjusts the temperature precisely by adding or removing material from the mound. A Victorian example is the Malleefowl. Some bird species avoid building their own nest, thus saving themselves a lot of trouble, and place their eggs in the nest of another bird. Cuckoos are experts at this trick. Yet other species lay their eggs in a shallow scrape on the beach (e.g., Hooded Plover).

Birds have a wide range of breeding systems. There are monogamous pairs right through to group arrangements where subordinates assist breeding individuals to rear their young.

Australian Wood Ducks (*Chenonetta jubata*) at a large breeding hollow. Hollows provide shelter from extreme weather and refuge from most predators. © Juliet Lowther.

Spider web is used as a construction material by birds for nest building. It is five times stronger than steel by weight. © Stephen Platt.

Nests also provide a clue to the life led by different birds. Many use tree hollows where the entrance can be guarded against egg-thieves and predators (e.g., parrots and cockatoos, Black and Wood Duck). Others weave a tight nest out of grasses and spider web carefully camouflaged with moss and lichen (e.g., Flame Robin) and perched high up or on a slender limb hanging over a waterway, making it difficult for predators to reach (e.g., White-faced Heron). Then there are the mud nesters, such as White-winged Choughs, Apostlebirds, Fairy Martins and Swallows that construct a nest of mud – on a branch in the case of choughs, in a cave or under an overhang in the case of Fairy Martins and swallows. Mud construction allows the nest to be built on any suitable surface.
Large birds of prey, such as eagles, build large stick platforms high in a tree top, as do waterbirds such as ibis and herons. Peregrine Falcons choose rock ledges on inaccessible cliffs, easily spotted by looking for the white stains of droppings immediately below the ledge. Brolga and swans build platforms out of reeds piled over water. Penguins, prions, Spotted Pardalotes and shearwaters dig burrows. Many small birds, including the finches, emu-wrens and fairy-wrens, place their domed (bottle-lying-on-its-side) nest in dense, thorny, inaccessible shrubs.
All birds face similar problems in nesting – predators, parasites and disease, protection from weather, chick safety and the need to exit the nest safely, to maintain cleanliness (droppings), and so on. For perching birds, the average number of fledglings produced per egg laid is just under half (0.46).[442] So, for all their effort, just one in two eggs will produce a chick that will live long enough to fly off the nest. The enormity of successfully rearing young requires talent and this knowledge grows with experience.

Magpie-larks ('mudlark')(*Grallina cyanoleuca*) build a mud nest. This provides some flexibility in where a nest is positioned. The design must cope with rainfall that could flood the eggs or wash the entire structure away. © Juliet Lowther.

This Grey Butcherbird (*Cracticus torquatus*) is stealing nesting material from the mudlark's nest (above) to line its own just 50m away. © Juliet Lowther.

Many birds harvest spider web to help construct their nest, such as the Varied Sitella (*Daphoenositta chrysoptera)* which also camouflages its nest with strips of bark.
© Ian McCann DELWP. CC 3.0 (Aust.).

Birds, such as these Rainbow Lorikeets, enjoy the huge advantages of flight including the ability to travel large distances quickly, easy access to food in the treetops and the insulation of feathers. They share the air with bats and some invertebrates. © Stephen Platt.

Cape Barren Goose (*Cereopsis novaehollandiae*) in flight, French Island. © Juliet Lowther.

The small (25–40 gram) Red-necked Stint (*Calidris ruficollis*) migrates to breed in the Siberian tundra, a journey of thousands of kilometres.

Movement

A capacity for flight confers many advantages on birds. They can travel large distances very efficiently and perch away from ground-based predators.

Whilst most bird species are resident year-round and territorial, others fly enormous distances to breed in the northern hemisphere when food is abundant. For example, the Common Sandpiper (*Actitis hypoleucos)* flies thousands of kilometres to Eurasia.

Some birds migrate vertically choosing lower altitudes when snow and blizzards make high elevations unsafe (e.g., Flame Robin [*Petroica phoenicea]*).

Migration routes are taught, in long-lived species, or genetically coded in short-lived species. Navigation involves one or more senses. They may use the sun as a compass, the Earth's magnetic fields, olfactory cues, and visual landmarks to find their way.

Flocking together, as many birds do when travelling (e.g., Budgerigar, Rainbow Lorikeet), confers a degree of safety from predators).

Twice a year, every year, Latham's Snipe (*Gallinago hardwickii) fly non-stop for five days, covering thousands of kilometres*, between freshwater feeding wetlands in Australia and their breeding habitat in Japan.

The Far Eastern Curlew is the largest wader in Victoria. It is found along the coast in summer where it probes mudflats for crabs with its long beak. It breeds thousands of kilometres away in marshes in the northern hemisphere.

Shelter

Birds need shelter from predators and climate. They use many places including tree hollows (parrots), dense bushes (wrens, scrub-wrens), phytofall (Bush Thick-knee), islands (gannets & albatross), hard-to-reach branches (thornbills), marine promontories (waders) and burrows (penguins, shearwaters).

Predators take a hefty toll on bird eggs and chicks. Nest predation rates can be as high as 71%[443], mostly (62%) taken by other birds.

Sleep

Birds can keep half their brain awake while the other half sleeps. This stops them falling off their perch and, when roosting at night, they can remain wary of predators.

Ecological role

Birds contribute to ecological health in many ways including as pollinators, cultivators, seed dispersers, by consuming carrion and by controlling invertebrates. They are important in food webs as predators and prey.

Dusky Woodswallows (*Artamus cyanopterus*) cluster at night. Sometimes in groups of hundreds. The most likely reasons are for shelter from weather, social cohesion and protection from predators, the cluster 'exploding' with birds and noise if approached. © Chris Clarke CC-BY-NC 4.0 (Int). [444]

'I'm not here' – camouflage in colouration and attitude (elongating its body to look more like a branch) is the Tawny Frogmouth's (*Podargus strigoides*) defence against potential predators. © Stephen Platt.

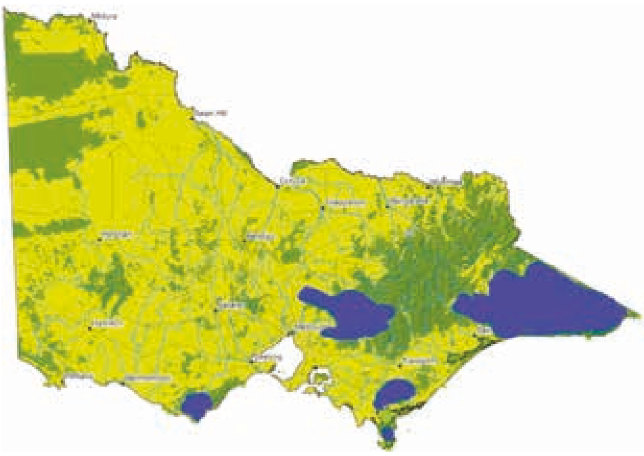
Ravens are harassing this Tawny Frogmouth. © Stephen Platt.

The wet forests – remnants of times past

Dappled light, fallen logs, tall tree ferns, mosses, a clear, gravel-bottomed stream. What can they tell us about this habitat? © Stephen Platt.

The wet forests – remnants of times past

***VEGETATION THAT** dinosaurs roamed, a fiery dance between forest types, a defensive skirt, gifts of blue, pixie's parasols, launch pads for tree ferns, 'chook' brawls, truffle hunters, able to sing before birth, blood-sucking worms – humans have a dichotomous relationship with wet forest – we love their grandeur and mystery but dislike their damp, leech-ridden, impenetrable unfriendliness.*



Approximate location of wet forests, including rainforest, in Victoria.

A wet forest of towering eucalypts over shrubs (Christmas Bush, *Prostanthera lasianthos,* in flower) and ferns. The paucity of very large trees is probably a legacy of previous logging. © Stephen Platt.

Low light, an abundance of ferns, and moss-covered logs characterise this rainforest near Cyathea Falls at Tarra Bulga National Park. In the background, eucalypts have invaded with the last fire. © Michael Barnett. CC BY-SA 3.0.

Introduction

IN A dry country like Australia, wet forests are in the minority. This wasn't always so. Before Australia split from Gondwana, about 100 million years ago, wet conifer forests, the birthplace of current rainforest plants, were widespread.[445] As the Australian continent drifted northward, reduced rainfall and more fire has pushed the wet forests to the coastal fringe, to high altitudes and into steep-sided gullies or rocky gorges where water is plentiful and fire a rarity. Fire is the intermediary that converts rainforest into tall wet eucalypt forest, at least temporarily. The distribution of rainforests and tall wet forests we see today is a reflection of this long history.

These are some of the most evocative forests to humans, with their straight trunks forming cathedral-like spires and eucalypts dwarfing us in height and bulk. Wet forests, excluding rainforest which is protected, are also the most productive forests and so the target of timber harvesting.

Rainforest – ecosystem outline

WALK INTO a Cool Temperate Rainforest and you are at once overcome by the cool, calm, dark, dank and enclosing world you have entered. It is a step back in time to the vegetation types that were around when dinosaurs roamed Victoria over 60 million years ago and vast swamps laid down the huge coal deposits in the LaTrobe Valley. It is a beautiful, lush, green world of climbers (lianas), ferns and mosses, plants growing on others (epiphytes) and diverse trees crowded together with low light at ground level.

Rainforest has a closed canopy with, when you look skyward, at least 70% foliage cover. Combined with topography, this prevents the entry of sunlight to ground level for much of the day. Broad-leaved plants are common, particularly in the understorey where extra leaf area can capture whatever light that is available. Humidity brings with it the risk of fungal infections, so leaves frequently have a 'drip tip' to help drain water from the leaf surface. There is a large variety of species and life forms. Eucalypts may be present as emergent trees following prior disturbance but are not dominant.

Today you will find isolated pockets of rainforest in places with reliable and high rainfall (800–1500mm per annum) and natural, topographic protection from fire (in fire refuges), such as deep inside a steep gully or among the rocks of a cliff-face. Rainforest plants generally do not cope well with fire, are thin-barked, and lack the regenerative epicormic buds of eucalypts.

High rainfall and all that goes with it – rapid turnover of large volumes of phytofall through the action of decomposers including bacteria, fungi, invertebrates and other animals; nutrient-rich, deep, loamy soils; low risk of fire and strong competition amongst plants for light – defines this ecosystem.

More than any other factor, high rainfall with low variability determines the potential extent of rainforest in Victoria. But not all sites with sufficient rainfall support rainforest. That is primarily because of fire and to a lesser extent soil fertility. Intolerance of fire sets the limits of rainforest distribution at any point in time.

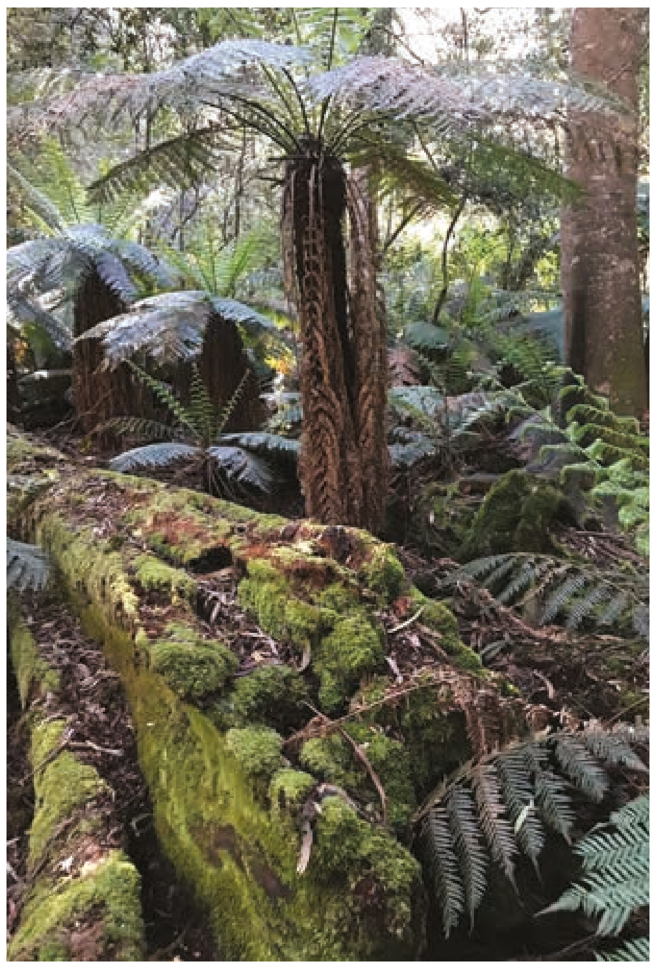
Most rainforests grow on fertile soils – marine sediments, alluviums, granitic, limestone and rarely, if they are protected from fire by bodies of water or topography, infertile coastal sand dunes and sea cliffs. Rainforests growing on sand are a testament to the extraordinary level of recycling that occurs in this forest type. Even infertile sands can be occupied by plants that take advantage of airborne nutrient inputs.

In most seasons, wet fuel conditions prevent fire in rainforest and will halt the passage of a fire. However, following prolonged drought, rainforest may burn.

The effects of fire disturbance on rainforest are complex.[446,447,448] Some species are partially tolerant to a single fire event whilst others may be killed by just one fire. However, the overall, long-term effect of recurring, extensive, intense fire is that it promotes eucalypt forest at the expense of rainforest and vice-versa.[449] In the absence of fire, rainforest will colonise wet forests and, with the passage of time, dominate suitable sites. Emergent, tall eucalypts within the rainforest are a sure sign of previous fire disturbance. They will disappear once their lifespan is reached and they fall because the low light conditions of the rainforest understorey prevent germination of their seed. Fire is thus an intermediary that determines whether rainforest expands or contracts in range.

Several types of rainforest are recognised. **Cool Temperate Rainforest** occurs at higher altitude (>700m) and with higher rainfall (1100–1500mm). Characteristic species are Myrtle Beech (*Nothofagus cunninghamii*), Black Oliveberry (*Elaeocarpus holopetalus*) and Southern Sassafras (*Atherosperma moschatum*). **Warm Temperate Rainforest** occurs at lower altitude (200–1000m) and lower rainfall (700–1100mm) along steep gullies. Typical tree species include Lilly Pilly (*Syzygium smithii*) and Blackwood (*Acacia melanoxylon*). **Dry rainforest** occurs only in fire protected cliffs and rock screes of East Gippsland. It requires a reliable summer rainfall.

Animal distribution of propagules is important in an ecosystem that occurs as small patches with minimal wind penetration. Many species of rainforest plant produce fleshy fruits in purple, red and yellow hues and this is attractive to birds such as the Satin Bowerbird (*Ptilonorhynchus violaceus*), Bassian Thrush (*Zoothera lunulate*), Pilotbird (*Pycnoptilus floccosus*) and Wonga Pigeon (*Leucosarcia melanoleuca*).



The environment of ferns, mosses, climbing plants (lianas) and a dense canopy of broad-leaved shrubs and trees allows little light to penetrate to the ground. © Stephen Platt.

Plant life

RAINFORESTS HAVE a diverse flora. Over 80% of the plant species that occur in rainforest are confined to it.[450] They contain 4% of the State's flora yet occupy less than 0.153% of its area.[451] Eucalypts are absent, except as emergent trees where they have gained a foothold through prior disturbance.

Rainforest plants tend to be fast-growing due to intense competition for light. Seed germination is not cued by fire as it is in many other systems and occurs continuously. Every four to six years Myrtle Beech (*Nothofagus cunninghamii*) has a heavier crop of seeds, called the 'beech mast'. These years of excess are usually explained as a way of overwhelming seed predators – there is so much seed that it is impossible for them to consume it. Gaps in the canopy, that admit light, as a result of a plant death, storm, flood, tree collapse or landslip, can create opportunities for new rainforest canopy plants to establish. Many species are shade tolerant and germinate under the closed canopy.

New foliage on a Myrtle Beech. © Reiner Richter. CC 4.0 (Int).

The worldwide distribution (Australia, New Guinea, New Zealand, New Caledonia, Argentina, and Chile) of *Nothofagus* spp. is indicative of the breakup of Gondwana. Ancient beech trees maintained a foothold on the separating landmasses. Source: Wiki Commons.

A forest giant that, despite being scarred, has survived many previous fires. Errinundra N.P. © Stephen Platt.

Lilly Pilly (*Syzygium smithii*), is a characteristic tree of Warm Temperate Rainforest. It produces fruits that attract wildlife. Michael M. Keogh. CC BY-NC 4.0 (Int.).

Kanooka (*Tristaniopsis laurina*) dominates riparian areas due to its flood tolerance. It occurs in East Gippsland Warm Temperate Rainforest. Mitchell River N.P. © Stephen Platt.

Abundant ferns and rope-like, climbing plants (lianas) are a feature of rainforest ecosystems. Mitchell River N.P. © Stephen Platt.

Animal life

LESS THAN a dozen vertebrate animal species can be said to be largely dependent on rainforest – Grey-headed Flying-fox (*Pteropus poliocephalus)*, Brown Gerygone (*Gerygone mouki)*, Black-faced Monarch (*Monarcha melanopsis)*, Large-billed Scrubwren (*Sericornis magnirostris)*, Sooty Owl (*Tyto teneibricosa)*, Satin Bowerbird (*Ptilonorynchus violaceus)*, Lewin's Honeyeater (*Meliphaga lewinii)*, Pink Robin (*Petroica radinogaster)*, Giant Barred Frog (*Mixophes balbus)* and Variegated River Tree Frog (*Litoria citropa)*.[452]

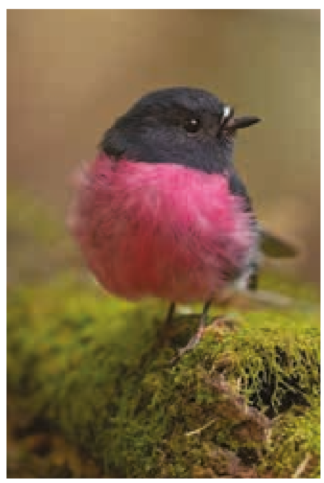
Most of the terrestrial rainforest mammals – rats, antechinus, quoll, wombat, echidna, wallabies, bandicoots – live solitary lives. A solitary life is typical of animals that gain no benefit from congregating, benefits such as mutual defence, attracting mates (e.g., communal breeding displays – 'lekking') or avoiding predation, problems associated with living in wide-open habitats such as grasslands or the open ocean.

Food sources – including fruits, invertebrates, and fungi – are a significant factor in determining which animal species thrive here.

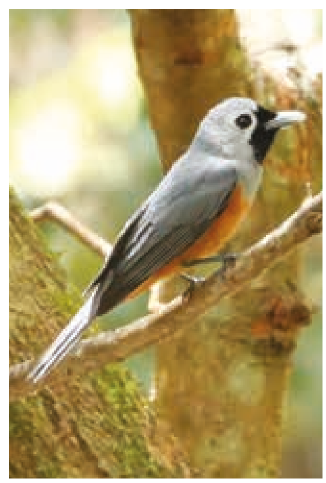
The male Satin Bowerbird (*Ptilonorhynchus violaceus*) builds a bower which functions as a courtship arena. He uses saliva and chewed plants to paste together two parallel walls of sticks, and decorates their surrounds with bright blue objects such as a parrot feather. When an interested female arrives, he performs a dance accompanied by a variety of calls whilst holding one of the blue objects in his beak. If she is suitably impressed, mating takes place in the bower but she then leaves alone to build a loose nest of sticks high up in a tree whilst he prepares to attract another female to the bower.

Mature male Bowerbirds lead solitary lives whilst younger males and females may form relatively large flocks.[453] Bowerbirds eat rainforest fruits. Having passed through the bird's gut, the seeds contained in the fruit are thus dispersed in the Bowerbird's droppings throughout the forest.

A female Satin Bowerbird inspects the arena (bower) of her potential male partner. © Steve Parish.



Pink Robins (*Petroica radinogaster*, male shown) occupy rainforest habitats seasonally. They use Myrtle Beech for nesting in spring and summer, then migrate to warmer sites in winter. © J J Harrison. CC SA 4.0 (Int).



Black-faced Monarch (*Monarcha melanopsis*), Mitchell River N.P. © Stephen Platt.

Bird sight

The colour of some plant flowers and fruits is linked to the eyesight of the birds they seek to attract. Birds have the largest eyes for their body size in the animal kingdom and around two and a half times the number of optic nerve fibres compared to humans.[454,455] Good eyesight is essential for flight. Bats have solved this problem in a completely different way, through echolocation, which allows them to hunt in the dark. A bird's eye is flatter than a human's eye so that more of their view is in focus. Birds have a third 'eyelid' that keeps the eye moist. The ability to see at night depends on the distance between the lens and retina. Thus, small birds are forced to be active in the daytime (diurnal) because their eyes are not large enough for night vision. In comparison, Owl eyes are very large. Many birds, including parrots, can see ultraviolet light but humans cannot.

The Wonga Pigeon (*Leucosarcia melanoleuca*) feeds exclusively on the ground seeking seeds, fruits and occasional invertebrates. © Kaitlyn. CC-BY-NC 4.0 (Int).

Tall wet forests – ecosystem outline

OVER A lifetime, David Ashton (Associate Professor of Botany, University of Melbourne[456]) observed changes in the Mountain Ash (*Eucalyptus regnans*) forest at Wallaby Creek, just north of Melbourne. In 1949, he saw a mature, even-aged, 230-year-old forest towering over three types of understorey. In the following 48 years the trees were depleted by death and windthrow. The understorey was severely damaged by sporadic heavy snowfalls and insect and fungal attack. Over time the area covered by ferns doubled to 80% despite occasional droughts. No eucalypt regeneration occurred. In contrast, in gullies where rainforest was present, rotting logs and up-thrown root balls provided places for rainforest trees to regenerate. There were changes in shrub dominance beneath the trees with Musk Daisy Bush (*Olearia argophylla*) dominating some areas and Hazel Pomaderris (*Pomaderris aspera*) invading others. Wetlands and riversides were invaded by a rainforest tree, Southern Sassafras (*Atherosperma moschatum*).[457] Rather than being static, the forest was in continuous flux.

Prophetically he wrote: "Whether the Big Ash will be spared from fire in future centuries is very doubtful." It wasn't. In February 2009, the Black Saturday bushfires burnt most of the Mountain Ash at Wallaby Creek. Thus, the ecosystem started a new cycle along a familiar path. If it matures before another fire it will resemble the mature forests before it but it is unlikely to be precisely the same. Rather than thinking that there is a pathway that leads to the same endpoint (a 'climax' community), scientists now think of the forest as going from one state and transitioning to another (state and transition model of vegetation change). Whilst the start points and ecological drivers are largely the same, the end point may not be. The 'Big Ash's' relationship with fire is a fascinating one. Fire seems so destructive of the ecosystem and yet without it the tall wet forests would not exist.

Mountain Ash at Wallaby Creek following the 2009 bushfires. The parent trees have all died but they are rapidly being replaced. July 2012. © Stephen Platt.

Musk Daisy Bush (*Olearia argophylla*). © Reiner Richter. CC-BY 4.0 (Int).

Rufous Fantails migrate south to breed in Victoria's wet forests during spring and summer. © McCann collection, DELWP. CC 3.0 (Aust.).

Looking skyward in a tall eucalypt forest. © Stephen Platt.

Eurabbie (*Eucalyptus globulus* subsp. *bicostata*) in the Otways. © Stephen Platt.

The tall wet forests of Victoria are dominated by species of fast-growing eucalyptus including Mountain Ash (*E. regnans*), Alpine Ash (*E. delegatensis*), Silvertop (*E. nitens*). Blue Gum (*E. globulus*) and Messmate (*E. obliqua*). A site is often dominated by one species which is able to outcompete other contenders.

Despite the density of the canopy, up to 40% of sunlight is let through. Understorey plants may be luxuriant with tall shrubs, ferns and tree ferns on wet sites. Drier sites have a grass-shrub understorey and nutrient poor, dry sites are occupied by small-leaved, tough (sclerophyllous) shrubs.[458]

In the late 1980s David Lindenmayer began studying the Mountain Ash forests in the central highlands of Victoria and, in particular, Leadbeater's Possum. His studies confirm that forest processes in Mountain Ash ecosystems are connected to forest pattern and structure. A patch of rainforest may affect the spread of a fire. The distribution of hollow-bearing trees affects where you will find arboreal mammals. A fire can affect nutrient recycling and so on.[459] Thus, to understand the forest patch you may be standing in; you need to look both within it and beyond it to the surrounding landscape.

Tall wet forests are very much three-dimensional structures. Different animal species exploit the resources within the ground, mid-storey and upper canopy layers. Birds are the most diverse vertebrate group in these forests with over 70 species observed in Mountain Ash Forest.[460,461,462] Through partitioning the forest – by structural layer, by food source, by time of activity and so on – more species can live here with less direct competition between them. Rufous Fantails (*Rhipidura rufifrons*) feed and breed in the middle and lower levels of the forest. They are forever flittering about whilst fanning their tail, which flashes red when backlit, to disturb their insect prey. In contrast, Pink Robins usually take invertebrate prey from the ground or low bushes.

Tall wet forests have a diverse arboreal mammal fauna. Most of the species are dependent on big, old, hollow-bearing trees. Only old trees (>70–120 years) produce hollows. You are most likely to find arboreal marsupials in areas of the forest with abundant hollows. But not all hollows are suitable. Greater Glider (*Petauroides volans)* are found in very tall trees with large, hollow branches 40 metres above ground. In contrast, Mountain Brush-tailed Possum (*Trichosurus cunninghami)* prefers large hollows but with less of a climb, hollows being around 25 metres from ground level. The context of the hollow is also important in terms of climate (north and north west facing hollows have low rates of occupancy – too hot) and what food is around.[463] Leadbeater's Possums (*Gymnobelidus leadbeateri*) select short, fat trees with numerous holes and a large quantity of dense surrounding understorey vegetation. Sugar Gliders *(Petaurus breviceps)* prefer trees with a large number of fissures, whereas trees favoured by Agile Antechinus (*Antechinus agilis)* are tall and thin. Trees selected as nest sites by Mountain Brush-tailed Possums are typically short and fat with few holes.[464]

It is unusual for multiple species to occupy one nest tree (less than 1%). Animals move between den sites to reduce the risk of predation and to manage parasites and disease. Mountain Brush-tailed Possums move between up to 20 different dens although most of their time is spent in just a few. Den sharing by up to six animals has been observed.

The thin, gum-barked eucalypts in wet forests, as they expand in girth, produce vast quantities of bark 'streamers' which in turn provide habitat for invertebrates such as spiders and predatory wingless tree crickets.[465] These in turn are food for small mammals and birds.[466]

Bark stringers at the base of a Brittle Gum *E. dalrympleana*. © Stephen Platt.

The forest floor is criss-crossed with fallen logs, branches and tree crowns. Annual phytofall is high by world standards at 7.66 tonnes per hectare.[467] As trees collapse, they briefly allow light to reach the forest floor and provide a surface on which plants can germinate. They do not contribute to fire risk which largely comes from leaves, fine branches and bark.

In the damp forest-floor conditions, where invertebrates and fungi thrive, phytofall rapidly decays returning nutrients to the soil. Superb Lyrebirds contribute to this process by raking the ground layer.

Invertebrates play numerous roles, including as decomposers and recyclers, as food sources, disruptors, predators and prey. For example, termites are endemic to these forests and aid the breakdown and recycling of wood. Occasional outbreaks of Spur-legged Phasmid (*Didymuria violescens*) and a psyllid insect (*Cardiaspina bilobata*) have been recorded. Between 1964 and 1976 the former defoliated 2,600 ha of Mountain Ash regrowth. After successive events over 80% of trees were killed.[468]

Fungi assist in the rapid recycling of nutrients. Bracket fungus, Errinundra N.P. © Stephen Platt.

Fire is infrequent in wet forests though often of great intensity when it occurs. Stand-replacing fires occur approximately every 75–150 years and less severe fires every 37–75 years.[469] Whilst the eucalypts in these wet forests are fire-adapted, they have lost the ability to resprout and instead are obligate seed regenerators. This makes them particularly vulnerable to multiple fires in quick succession. Should a second fire occur before they reach sexual maturity at 15–30 years, they will be replaced by other species.

The dominant eucalypts store their seeds in woody, fire-resistant fruits in the canopy. Fire stimulates a mass release of seeds. Mountain Ash live to around 400+ years.[470]

Bushfire risk is not uniform over time. The probability of a bushfire increases rapidly for the first hundred years then declines as quickly over the next 100 years as ferns, grasses and rainforest species replace dense shrubs. Fire risk remains low as the community continues to age from 200–350+ years.[471]

Because wet forests rarely burn compared to the broader landscape, they can act as a refuge for wildlife. Animals flee here and remain until their burnt forest homes regenerate. Most (94%) wet forest birds have a negative response to more fire in the surrounding landscape.[472] In other words, there are fewer of them if the landscape is burnt even if their immediate habitat is untouched.

Fires do not necessarily affect all of the landscape in the same way. Patchiness in the severity of a fire means that some areas are unburnt, some scorched but living, and some killed. A study of the fire history of a tall wet forest in Tasmania found that 57% had remained unburnt since 1850 and that one stand of very old trees had survived to over 450 years of age.[473] This patchiness in vegetation flows through to greater diversity of habitats for wildlife.

The abundance of shrubs, tree ferns and wattles vary with the age of stands.[474] Bird diversity is greatest in the older stands.

In this image we see the end of an invasion. A fire some hundreds of years ago allowed ingress of Mountain Ash (*Eucalyptus regnans*) into a patch of rainforest. The eucalypt seedlings grew fast, matured and are now reaching their lifespan and collapsing (tree at left). During this time, rainforest species such as Myrtle Beech (*Nothofagus cunninghamii*) and Southern Sassafras (*Atherosperma moschatum*) have regrown in the understorey. They often begin life on fallen, rotting logs or tree fern crowns. Their density prevents light penetration and stops germination of eucalypt seed. Once the old eucalypts have all fallen, without a fresh supply of eucalypt recruits the site will return to its former rainforest vegetation. That is, unless there is another fire. © Stephen Platt.

Ingress into the rainforest ends for this forest giant with its collapse, decay and return of nutrients to the soil. It wouldn't have been here without a fire many years ago. Shade will prevent the return of more eucalypts until the next fire.
© Stephen Platt.

The charcoaled tree at centre was dead before a fire killed its neighbours. © Stephen Platt.

Abundant and reliable water sustains the closed-canopy, wet forests. © Stephen Platt.

Plant life

SOFT TREE-FERN (*Dicksonia antarctica*) occurs in wet valleys. It is habitat for many other species such as Grey Shrike-thrush (*Colluricincla harmonica*) and Golden Whistler (*Pachycephala pectoralis*), which may nest in the crown. Many other plants live on these ferns which have fossil relatives dating back 150 million years. In a Tasmanian study, a total of 97 fern and bryophyte species were recorded on Soft Tree Fern from 120 trunks at 10 sites.[475] Tree ferns may be long-lived, in the order of 300–400 years.[476] Thus, they must be capable of surviving the numerous fires that occur over such a long timeframe. They are extremely successful at this. Tree ferns are one of the first plants to respond after a bushfire.

So why don't the trunks of old tree ferns look black when they have been burnt, in some cases many times? Unlike Grass Trees, where the trunk remains blackened, the Tree-fern trunk (caudex) is constructed of aerial 'roots' which, after fire, rapidly grow out and cover those burnt in the fire.

Golden Whistler (*Pachycephala pectoralis*). © Stephen Platt.

Tree fern regeneration following Black Saturday bushfires 2009, Robertson Gully, Marysville. © Stephen Platt.

Tree fern trunk – note the blackened surface between the new 'roots' that have nearly covered it. © Stephen Platt.

As tree ferns produce new fronds, so the older ones go limp and hang down. These 'skirts' may be a defence against climbing plants and epiphytes.[477] The new fronds are a favourite food of Mountain Brush-tailed Possum.

The wet soil beneath tree ferns is where forest 'truffles' (hypogeal fungi) develop.[478]

The pithy cores of tree ferns were eaten by Aborigines.[479]

Fungal threads (hyphae) of the Pixie's Parasol (*Mycena interrupta*) are spread throughout this log. They will decompose the dead wood of this fallen Mountain Ash, thus releasing nutrients for other species. The fungal fruiting body ('mushroom') indicates the otherwise unseen activity going on inside the log. © Stephen Platt.

Animal life

Leadbeater's Possum build a nest of stripped bark high up in a hollow of an old, living or dead Mountain Ash. Up to twelve individuals live together. They will only occupy habitat where their den tree is surrounded by wattles which form a dense mid-storey. The wattles provide cover for safe movement and harbour food including arthropods, particularly tree crickets, beetles, moths, and spiders, plant exudates such as Acacia gum, nectar, manna, and honeydew.[480]

Leadbeater's Possum feeds on the sap of Silver *(Acacia dealbata*), Forest (*A. frigescens)* and Mountain Hickory Wattle (*A. obliquinervia*). It gnaws the bark to stimulate flow, leaving behind tell-tale crosshatched marks. © Tim Bawden. CC BY 4.0 (Int.).

Long-footed Potoroo *(Potoroo longipes)*.
Department of Agriculture, Water and the Environment. CC BY-SA 4.0

At ground level, hidden from human view, is a food source that sustains medium-sized mammals, including potoroos and bandicoots, and maintains forest health. Underground fruits of fungi (termed hypogeal) are the truffles of Victoria's forests. They make up around 91% of the diet of the Long-footed Potoroo (*Potorous longipes*), which consume fruits of at least 58 fungal species.[481,482] The fungi that produce these underground mushrooms associate with the roots of forest trees (termed mycorrhizae). Up to 8kg of native truffles per hectare per month may be produced in forest soils.[483] The fungus provides the forest trees with water and nutrients. It may also protect the host plant from root pathogens. In return, the tree probably supplies the products of photosynthesis to the fungus, as fungi are unable to photosynthesise. It is estimated that there may be over 1,000 species of native truffles Australia-wide.[484] It has also been reported that native truffles smell more strongly after bushfire, which may aid their discovery and distribution at a time when the forest is in transition with many new saplings to infest.

Birds of wet forests include Australian King-Parrot (*Alisterus scapularis*), Rufous Fantail (*Rhipidura rufifrons*), Rose Robin (*Petroica rosea*), Superb Lyrebird (*Menura novaehollandiae*), Eastern Whipbird (*Psophodes olivaceus*), Bassian Thrush (*Zoothera lunulate*), Pilotbird (*Pycnoptilus floccosus*), Large-billed Scrubwren (*Sericornis magnirostra*), Sooty Owl (*Tyto tenebricosa*), Lewin's Honeyeater (*Meliphaga lewinii*) and Satin Bowerbird (*Ptilonorhynchus violaceus*).

Superb Lyrebirds transform their habitat by speeding up decomposition. Male displaying.

The first evidence you might encounter of this bird is the male's remarkable song. Heard most stridently in winter and at daybreak – a series of its own and other birds' vocalizations. Wild Superb Lyrebirds (*Menura novaehollandiae*) rarely make human-origin sounds. They are one of the bird worlds best song-masters and mimics. Songs are used to advertise territory and as a directional beacon for females to locate males. Immature male Superb Lyrebirds learn their song from adult males and may add or delete sounds from his repertoire.[485] The specific song varies from place to place with unique song types developing in acoustically isolated areas (each Lyrebird mimics its neighbour's song) and song elements pass down through generations as shown by Superb Lyrebirds introduced to Tasmanian in the 1930s mimicking mainland Whipbirds thirty years later.

At dawn, he will glide down from his night-time roost high in the tree canopy and begin foraging on the forest floor. These are the 'chooks' (also called 'ecosystem engineers') of the Victorian wet forests, scratching away at phytofall in search of invertebrates, and the occasional frog or lizard. They are so effective at turning over the ground layer that they significantly speed up plant decomposition and so help to reduce the fine organic material that fuels bushfires.[486] Some 200 tonnes of phytofall and soil may be displaced 70cm downhill per year by Lyrebird activity. More material is displaced by Superb Lyrebirds than any other soil-displacing animal worldwide.

Lyrebird scratching creates areas of bare ground, free of dense ground ferns. This assists in the establishment of Rough Tree-ferns (*Cyathea australis*) and forest herbs.[487] Thus, Lyrebird activity facilitates the forest patchiness of ground ferns in some areas, where Lyrebirds have not been active, and dense tree ferns in others, where they have.

You might come upon a circular patch of soil cleared of vegetation, amid dense bushland. This is his display area. When courting females, he will sing and display his magnificent tail feathers, agitating them to quiver while he prances around and sings. Up to 20 such platforms may be constructed across his territory. His 'plick' song will reach its highest volume as she enters the display area.

Female Superb Lyrebirds are far from the passive recipient of his attention. They will destroy rival female's nests and occasionally brawl with each other, legs intertwined whilst rolling around on the ground. They also sing, and mimic other sounds, but they select different sounds to males. She may sing to let other females know her territorial claim without the need for such risky scuffles. Further evidence suggests that her mimicry may be used specifically in response to the type of predator in the vicinity of a nest and may have the purpose of defending the nest from egg-predators including Goshawks, Currawongs and even much smaller Grey Shrike Thrushes.[488]

Being in possession of magnificent tail feathers has its down side. In 1862, Horace William Wheelwright recorded that "The blacks make periodical excursions up into the ranges, about September, when the birds are full-feathered, and come back laden with tails."[489] As early as 1824 a French naturalist, R.P. Lesson, learned during a visit to the Blue Mountains that the birds [lyrebirds] were becoming rare through being persistently hunted, and a few years later Dr G. Bennett wrote that the tails had become so scarce that the price had risen to 30 shillings a pair. In 1911, it was reported that 2,000 tails were exported to London in the previous three years for a retail price of two shillings sixpence a tail.

She lays just one egg in an untidy nest usually well hidden in a gully or sometimes a rock crevice. It may be at ground level or higher up and its architecture may be modified in response to seasonal variation in rainfall.[490] The female alone incubates the egg for 50 days. She will vocalise to the egg and the chick will begin to vocalise whilst still in its egg. This is an unusually long period of vulnerability to predators. With all her investment in a single chick, she needs to be an attentive and expert mother. Lyrebirds are long-lived (~30 yrs) and so have time to develop parenting skills.

Our knowledge of these amazing birds has been greatly informed by many people including the dedicated volunteer members of the Sherbrooke Lyrebird Study Group who have investigated Lyrebirds and protected their habitat since 1958.

Tom Tregellas (1864–1938), spent much of the 1920s and 1930s in a hollowed out log he called 'Menura' at Kallista in the Dandenong Ranges making observations of Superb Lyrebirds. © Museum Victoria/Photographer unknown.

Leech. © Doug Beckers. CC SA 2.0 Generic.

When you think of a worm, you don't usually think of it sucking your blood. Leeches, of which there are 500 kinds worldwide, are segmented worms that have specialised for sucking blood from their host which may be a mammal (including humans), fish, frog, turtle, or bird.

They are found in a wide range of habitats, particularly freshwater lakes, and can be abundant in wet and rain forests.

Leeches are hermaphrodites, meaning that they possess both male and female sex organs. Sexual reproduction involves two leeches intertwining their bodies with one depositing a packet of sperm in a thickened area of skin on the other. After fertilization, a tough, gelatinous cocoon is secreted and the eggs are deposited into it. The cocoon is attached to a rock, log or leaf. In weeks to months the young hatch and seek out a host to feed on. Some leech parents care for the cocoon until the young hatch and travel on their carer's body until reaching their first meal. Leeches live for just one to two reproductive events.[491,492] They can see, smell, and detect temperature and vibration. Whilst they are predatory blood suckers (sanguivorous), they are also prey for many forest-dwelling animals.[493,494]

In summary, the tall wet forest and rainforest ecosystems are driven by intense competition for light supported by a plentiful supply of reliable water. How much of each system is present at any one time is determined by fire which allows the tall eucalypts to germinate and occupy sites wet enough for rainforest. Without fire the rainforest boots the gums out by creating shade. It is a system in which nutrients are recycled with extreme efficiency. Few animal species specialise in living in these forests, possibly because they occupy only a small proportion of the overall landscape.

Cover image: The darkness suggests a closed canopy of rainforest species persist along the creek. No eucalypts are obvious, suggesting that severe fire has not penetrated close to the creek for a long time.

Where to see these ecosystems

- Yarra Ranges National Park
- Errinundra National Park
- Great Otway National Park
- Tarra Bulga National Park
- Kinglake National Park
- Wilson's Promontory National Park
- Snowy River National Park
- Mitchell River National Park
- Lake Mountain and Cumberland State Park
- Baw Baw National Park

The ecological role of logs and dead trees

WANDERING AROUND in the bush, it is easy to overlook the dead trees and fallen logs. They are the homes, the freeways, the larder and the lookout, for many plants and animals.

Logs and dead trees provide:

- shelter and nesting sites
- places to hunt for food
- basking and hibernation sites
- perches for birds when hunting
- places for lichens and fungi to grow
- when they decay, soil nutrients that support forest health.

Logs also provide:

- runways that assist movement
- plant germination sites
- wet places for invertebrates to hide during drought and fire.

Logs and dead trees play an important role in forest and woodland ecosystems.

Phytofall is a significant component of many ecosystems.
© Stephen Platt.

Logs act as runways for small forest mammals.
© Brett Vercoe. CC-BY-NC 4.0 (Int).

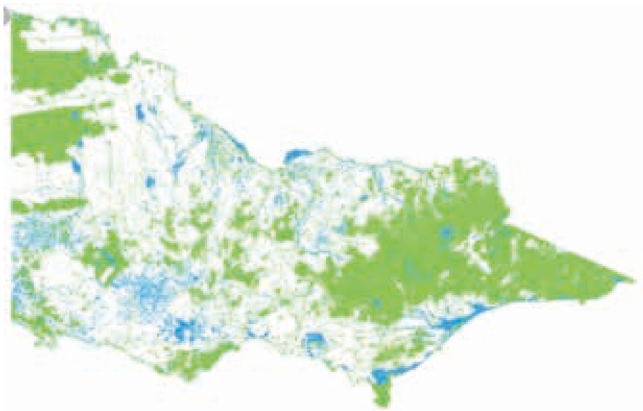
Dead trees are a normal, and important, part of a forest, often lasting decades before collapse. Thirty-six Lesser Long-eared Bats (*Nyctophilus geoffroyi*) exited the small crack in this dead tree. © Lindy Lumsden.

Wetlands and estuaries – water supports life

This is a wet site but what does the presence of Fairies' Aprons (*Utricularia dichotoma*) tell us? © Stephen Platt.

Wetlands and estuaries – water supports life

***A CARNIVOROUS** fairy, flour from a fern, hunted for its waterproof fur, a tall dancer, a journey of 3,000km under the sea, a night flyer that goes fishing, a creche for large-billed youngsters, paddling a raft of foam in which to float its eggs, wedged by salt – wetlands and estuaries are crucibles of life for many species.*



Victoria has over 35,000 wetlands (blue) of which 25,000 are naturally-occurring.[495]

Introduction

YOU PROBABLY know them as swamps, marshes or lakes. Wetlands are where you might have caught tadpoles, or watched waterbirds. They are a distinctive ecosystem supporting many plants and animals. Victoria has 12 RAMSAR sites of international importance[496,2] for their role in supporting migrating shorebirds.

Wetlands were utilised by Aboriginal people who developed sophisticated methods of trapping fish and eels and using wetland plants.[3]

Ecosystem outline – wetlands

WHERE WATER lies, either permanently or temporarily, a wetland is formed. Thus, the main difference to unflooded areas is that plants must cope with soil that is saturated with water and submerged for long or short periods. Wetlands differ from rivers and streams because the water is still. Often, only specialised plants and animals can manage in these conditions.

There is a great variety of wetland types. Permanent and temporary, large and small, shallow and deep, nutrient rich or poor, saline or freshwater. Each wetland has its unique combination of characteristics.

A wetland's water source may be rainfall, overland flows (such as overbank flow of rivers, or streams feeding wetlands), groundwater or a combination of these. They occur in many contexts (e.g., alpine to lowland, inland to coastal) and have varied underlying geologies. They can be low in nutrients (oligotrophic) or enriched in nutrients (eutrophic) naturally or as a result of human disturbance.

In Victoria, wetlands occur in large numbers along rivers, where meanders have been cut off the main channel (oxbow lakes, anabranches and billabongs); in alpine areas as bogs and peatlands, on the volcanic plains, particularly where lava flows have cut off natural water flow; and between ancient dunes in the Wimmera region. Lake Corangamite, near Colac, is Australia's largest permanent saline lake (230km^2 area, 150km circumference).

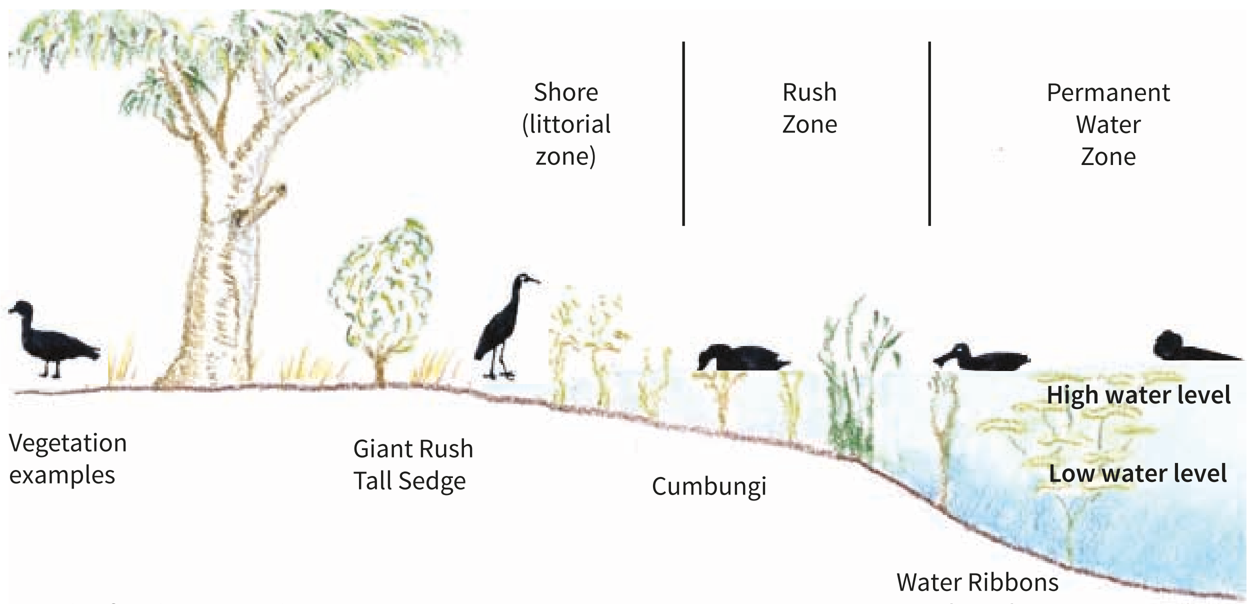
Basalt Plain wetlands south-west of Willaura, Victoria.
Source: Google Maps.

Oxbow wetlands of the Goulburn River at Yambuna.
Source: Google Maps.

2 The Ramsar Convention protects wetlands of international importance. Specific agreements (Jamba, Camba, Rokamba) are also in effect between Australia and China/Japan/Republic of Korea.

3 E.g., The World Heritage listed Lake Condah fish traps, which date back over 6,600 years.

Zonation in a permanent wetland



Waterbird feeding strategies

Australian Wood Duck – grazing on the wetland surrounds

White-faced Heron – fishing by stealth along shallow edges

Pacific Black Duck – dabbling for plant seeds and small invertebrates

Pink-eared Duck – filtering micro-organisms from surface water

Musk Duck – diving for invertebrates

Wetland size, depth, permanence, salinity, nutrients, isolation/landscape position, geology and history, influence what plants and animals are present.

Waterbirds adopt different feeding strategies to take advantage of the full range of wetland food sources.

The size, depth, connectivity, underlying geology, history and water regime of wetlands are influential on what vegetation and wildlife is present. As the plants change between wetland types, so do the animals.

Shallow, temporary (ephemeral) wetlands have a wet and dry phase. The vegetation is dominated by annual species or species which use bulbs or fleshy roots to survive drying. During dry phases, animal species may lie dormant as eggs or buried in the mud or soil. When flooded by winter rains nutrients released from plant material, broken down over summer or by inundation, stimulate plant and invertebrate growth and the breeding of frogs. Fish are usually absent and this provides tadpoles with respite from fish predation but not from predatory water beetles. Birds which have adapted to exploit these conditions include Pacific Black Duck (*Anas superciliosa*) and Grey Teal (*Anas gracilis*), which eat both plant material and invertebrates, and Black-winged Stilt (*Himantopus himantopus*), ibis and White-faced Heron (*Egretta novaehollandiae*), which eat invertebrates. Vegetation remaining from the previous inundation, together with new growth, provides nesting materials for waterbirds. Large quantities of material are used by some species (e.g., Black Swan [*Cygnus atratus*], Brolga [*Antigone rubicunda*]) while others build their nest above the water in emergent vegetation (e.g., Australasian Swamphen *Porphyrio melanotus*). Other waterbirds nest nearby in tree hollows (e.g., Australian Shelduck *Tadorna tadornoides*, Australian Wood Duck *Chenonetta jubata*) or dense vegetation (e.g., Pacific Black Duck, Australasian Shoveler (*Anas rhynchotis*). Newly-hatched young move to the wetland for protection from predators and to feed.

Stealth and keen eyesight has helped this Australasian Bittern (*Botaurus poiciloptilus*) to capture a Green and Golden Bell Frog (*Litoria aurea*). © Peter Menkhorst.

Pacific Black Duck (*Anas superciliosa*) and ducklings. They are mainly vegetarian, feeding on the seeds of aquatic plants. The nest is placed in a tree hollow. Pacific Black Ducks were a component of Aboriginal diet.[497] © Juliet Lowther.

The Yellow-billed Spoonbill (*Platalea flavipes*) feeds on aquatic insects and their larvae. It sweeps its bill from side-to-side. The bill is equipped with papillae that can detect prey vibrations. It works like an aeroplane wing, creating a pressure difference that draws in prey items. This spoonbill is able to feed in daylight or at night.
© John Manger, CSIRO. CC A 3.0 Unported.

Permanent wetlands offer a stable alternative to ephemeral wetlands with water available all year. Predators, such as fish and turtles, are usually present year-round. Waterbirds that prefer permanent wetlands include Great Egret, Little Pied Cormorant, Rufous Night Heron and Yellow-billed Spoonbill.

Where vegetation is sparse or low along the shoreline, Black-fronted Plovers and Red-kneed Dotterels will nest on the ground and migratory waders, such as Sharp-tailed Sandpiper and Latham's Snipe, which do not breed in Australia, may be seen feeding.

The wet/dry regime is important in wetland ecology. A study of temporary wetlands in western Victoria estimated that their water level was at least 10cm deep for 6.3 years out of ten during the twentieth century. On average they were dry for periods of 1.27 years.[498] Temporary wetlands had higher biodiversity than nearby permanent wetlands.

A challenge for most wetland inhabitants is how to move between wetlands – to find a mate, new food source or avoid competition – when they are surrounded by dry land. Some species hitch a ride with birds whilst others wait for floodwaters to carry them overland. Turtles just walk, being protected by their hard shell against predators and desiccation.

Unsurprisingly, fire is not a major factor in wetland ecosystems. However, shallow wetlands can dry out and fires may occur resulting in a sudden release of nutrients when the wetland refills.

Common Bottlebrush (*Callistemon citrinus*) occupies this shallow, seasonal wetland in east Gippsland. © Stephen Platt.

Due to Australia's variable climate, erratic rainfall and sporadic wetland habitats, many waterbirds respond to changes in habitat availability across the continent.[499] Their absence in Victoria might be due to better conditions elsewhere.

Plant life

AQUATIC PLANTS must cope with fluctuating water levels, submersion and drying out, obtaining sufficient oxygen and light in muddy water, nutrient inputs and dispersal between isolated water bodies. They have acquired many adaptations in response to the above challenges. Flexible leaves and stems allow aquatic plants to survive in strong currents (e.g., Water Milfoils), gas-filled cells allow leaves to float and permit photosynthesis in muddy waters (e.g., *Ornduffia reniformis*), specialised structures catch animals to obtain nutrients (Fairies Aprons), indigestible seeds deter seed predators and facilitate movement in the gut of birds (e.g., Nardoo).

Some wetland plants require inundation to germinate and will grow fully submerged (e.g., Eel Grass *Vallisneria* spp.). Other species require seasonal drying (e.g., *Phragmites australis*, Cumbungi *Typha* spp., Spike Sedge *Eleocharis* spp.). Some are free-floating (e.g., *Azolla* spp.).

The fruits and leaves of Water Milfoils (*Myriophyllum* spp.) are eaten by waterbirds. They provide shelter for fish and are good water oxygenators.

Alpine Water-milfoil (*Myriophyllum alpinum*). © Jackie Miles CC BY.

Running Marsh-flower (*Ornduffia reniformis*) has floating leaves and occurs in water up to 60cm deep. It 'runs' by using underwater stems (stolons) that take root and produce a new plant. © Russell Best CC-BY-NC 4.0 (Int).

Fairies' Aprons. © Stephen Platt.

Nardoo. © Robert Browne-Cooper. CC BY 4.0.

Pacific Azolla. © Johnnewm CC-BY-NC 4.0 (Int).

Fairies' Aprons (*Utricularia dichotoma*) look innocent enough with their beautiful violet flowers protruding from shallow water. But beneath the surface it is a different story. Hollow bladders on highly modified leaves are used to trap and eat minute animals. If the unfortunate animal touches sensitive hairs on the bladder, a flap-valve is opened and the rush of water carries the animal inside then closes again behind it. The trapped animal is then digested. Hence their other name, Bladderwort.

Nardoo (*Marsilea drummondii*) is an aquatic fern. It produces a fruit full of spores (sporocarp). These are consumed, but not digested, by birds that help to disperse the plant as they travel among wetlands. Spores also move with water flow. Nardoo sporocarps were ground to flour, mixed with water to form a dough and roasted by Aboriginal people as a food source. The uncooked flour contains a poison, thiaminase. It has been suggested that the explorers Burke and Wills, on their ill-fated expedition across the continent, due to their lack of knowledge about how to prepare Nardoo for eating, contributed to their own death.[500]

Pacific Azolla (*Azolla rubra*) forms extensive mats on slow-moving bodies of water such as streams, lakes, ponds and swamps. Under the right conditions, *Azolla* reproduces rapidly by vegetative growth and subdivision. Fragments travel with water flows to colonise new areas. The leaf surface repels water, thus preventing submersion.

Animal life

WATER, BEING essential for life, attracts wildlife. The duration of inundation, the depth, the level of oxygenation, the emergent, submerged and surrounding vegetation and the substrate are important factors in what wildlife will occur at a particular wetland.

You may first encounter them at dusk as their V-shaped bow-wave glints in the fading light. Or you may notice a pile of discarded fish bones, crayfish claws and shells on a log 'feeding table' at the water's edge. Water Rats (*Hydromys chrysogaster*), also called by their Aboriginal name 'Rakali', are semi-aquatic, opportunistic and mainly carnivorous feeders. Characteristically they swim along the water surface at sunset catching fish up to 36cm long, and collecting crustaceans, molluscs, yabbies, spiders, frogs, tortoises, birds, eggs and plant material.[501] They build burrows into banks and may have several litters in a season. Rakali produce one to seven pups in a litter, usually 4–5. Adulthood is achieved in less than a year.

Cold water can remove body heat. Rakali have dealt with this problem through luxuriant fur that traps air and keeps them warm. Following depression-era restrictions on the importation of American Muskrats to Australia, Water Rats were trapped for their waterproof, fur pelts until being 'protected' in 1938.[502] In 1931, a pelt was valued at four shillings. By the 1941 open season it was worth 10 shillings (equivalent to $41 in 2019).[503] One hundred pelts were required to make one coat.[504] Despite being overexploited last century, Water Rats have recovered and are widespread in Victoria today.

Water Rat. © James Bailey. CC BY-NC 4.0 (Int.).

A bat that goes fishing? The Fishing Bat (Large-footed Myotis, *Myotis macropus*) has extra-large feet that it uses to trawl through the surface water of lakes and slow-flowing streams seeking small fish and water beetles (water boatmen, whirligig beetles). It is the only bat to do so. Invertebrates are its main food type. During the day it roosts in dark places including tree hollows, under tree bark, under bridges, in mines and road culverts, that are near permanent water.[505] Males maintain a harem of around 12 females. In New South Wales, up to two young per female are born each year, one in January, the other in October.

Large-footed Myotis – the fishing bat. The large-footed Myotis has big feet (for a bat) that it uses to trawl surface water for prey such as beetles and small fish © Mark Sanders (Ecosmart Ecology).

Brolga attending its nest in a shallow freshwater wetland .

A large pile of vegetation in the middle of a shallow wetland may indicate the presence of a Brolga (*Antigone rubicunda*) nest. In it, a single clutch of eggs will be laid and guarded by both parents. Brolgas probably mate for life. Their pair bond is reinforced by an elaborate courtship dance – involving dancing, leaping, wing flapping and trumpeting – performed each breeding season and practiced at other times.

Outside the breeding season, Brolgas form large flocks. They feed on plant (wetland plants and their tubers) and animal (invertebrates, frogs, even mice) material.

Brolga were once much more abundant in Victoria but habitat loss and ongoing illegal hunting has reduced populations. Horace William Wheelwright (1862) writes:

"it is next to impossible to stalk them in the open; but, in the end of summer, they draw down to the edges of the creeks, and are then easily approached under cover of the tea-tree. I once dropped on a little mob of five in such a place, and I nailed three at a double shot; and well I recollect bringing them home on my back at night, about six miles, with five couple of black ducks and thirteen pigeons. An old bird will stand over five feet high, and weigh upwards of twenty pounds."[506]

Eastern Banjo Frog.

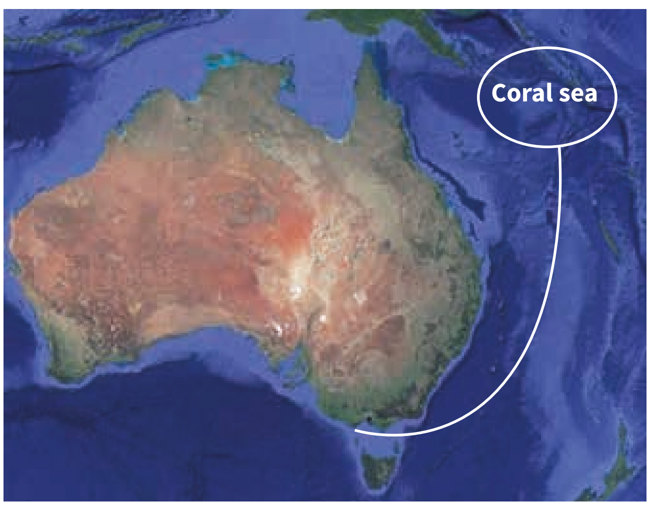
Calling male Pobblebonk Frog and egg mass.

The widespread Pobblebonk Frog (*Limnodynastes dumerilii*), also called Eastern Banjo Frog, is easily recognised by its characteristic, loud 'bonk' call. Only male frogs call to attract females and to warn off other males. As the breeding season approaches, the female grows flaps of skin called flanges on the first two digits of her feet. Mating occurs between August and April. After mating, the female will lay up to 4,000 eggs into a floating mass of foam that she creates using her arms, in the fashion of egg beaters, mixing air with a jelly-like secretion. She will care for her eggs by using her flanges to ladle air bubbles onto the foamy egg mass. Relatively large tadpoles hatch and feed primarily on micro-organisms living on aquatic vegetation. It takes up to 15 months before they change (metamorphose) into frogs.

What an extraordinary transition this is. Imagine being able to live underwater when young, then grow some legs and move onto land as you age. This transition is not a simple one. Breathing in particular must transform from gill structures, that can extract oxygen from water, to a lung that can do so from air. That's why keeping tadpoles in a container of water and not letting them get onto land as they grow legs leads to their death – they drown! Pobblebonks burrow underground to avoid predators, and emerge after rainfall. All frogs have poison glands on either side of the head as a defence against predators.

Frogs do not drink like we do; instead they absorb water directly through their skin in an area known as the 'drinking patch' located on their belly and the underside of their thighs.

Southern Shortfin Eel. © Nigel Marsh. CC BY-NC 4.0 (Int).



The extraordinary breeding migration route of the Short-finned Eel. Map source: Google maps.

They're slender, they're slimy, they're fish. Southern Shortfin Eels (*Anguilla australis*) live in the lakes, rivers and wetlands along Victoria's coast but not all the time. In one of nature's great migrations, female eels undertake an extraordinary journey, first swimming downstream to enter the sea and then for over 3,000km, at depths of up to 200m, to the Coral Sea where they deposit the millions of eggs they have carried.

They will not return as the energy expended getting there leads to their death. About a year later, the young glass eels that survive the perilous return journey will re-enter the streams of southern Victoria between mid-winter and late spring. For this to happen, a combination of large freshwater flows and 'slingshot' eddies off the east Australian current is required. In many years no young eels (elvers) make it to the estuaries where their inland life begins. Elvers can climb vertical walls until they reach 12cm or 5g in weight when they lose their climbing ability.[507] They can also travel short distances across moist ground.

Short-finned Eels are predatory carnivores eating crustaceans, fish, frogs and even small birds. They mature at 14 years (male), 18–24 years (female) and may live to a great age (~60 years).[508]

Aboriginal bands would gather by rivers waiting for the mass migration of eels. Stone barriers were used to divert tonnes of eels, followed by migrating native galaxid fish, into funnel-shaped baskets, at Lake Bolac, Lake Condah and elsewhere in western Victoria.

Elvers climbing a rock.
© Maryland Fishery Resources Office, USFWS. Public domain.

Common Yabby. © Daiju Azuma CC BY-SA 2.5 Generic.

Yabby eggs are carried about attached to the female's abdomen until hatched. © Livestock Industries/CSIRO. C.C. A3.0 unported.

Mosquito larvae can survive in most still bodies of water. © MDC Staff, courtesy Missouri Department of Conservation.

The Common Yabby (*Cherax destructor*) is found in wetlands at lower elevations, whilst spiny crayfish (*Eustacus* spp.) occur in environments at higher altitude. Yabbies are active at night. They eat dead organic material (are detritivores) that eat algae, plant, fish and other animal remains. Yabbies are important prey for Murray Cod and Golden Perch. In dry periods yabbies can survive for years lying dormant in burrows in the mud. They can travel up to 60km across land in search of a water body. Yabbies enter partial hibernation in the cooler months and so you are less likely to encounter them.

If you are being bitten by a mosquito, then it is a female. Within days of consuming a meal of blood, female mosquitos lay up to 200 eggs in a water body. These may be attached in a 'raft' and hatch within a few days. Mosquito larvae, or 'wrigglers', filter tiny organic particles from the water. They in turn are food for many aquatic species of invertebrate and fish. The young larvae must breathe air at the water's surface. As adults, both sexes feed on nectar and in doing so are pollinators of some plants. Whilst the adult female may live for a month, males rarely get past a week.

Of the 300 or so Australian species, only a dozen are responsible for transmission of diseases that affect humans. Mosquitos are perhaps the most dangerous animal on Earth because of the diseases they carry and number of humans that die from them (Malaria kills over one million children per year).[509] Locally in Victoria, the mosquito is largely seen as an irritation but never-the-less can carry serious diseases such as Ross River Virus.

How do they find us? Mosquitos initially home in on the carbon dioxide in animal breath, then on chemicals produced by bacteria and sweat on our bodies.

The Water Boatman feeds on plant material. © Peter J Bryant.

Water Boatmen (Corixidae) use their hairy hind limbs to propel themselves through their still-water habitat. They feed by injecting enzymes into plants and then sucking out the dissolved fluids. Eggs are laid on aquatic vegetation or other solid objects.

Ecosystem outline – estuaries

ESTUARIES, BAYS and inlets are unique habitats on account of their interface between freshwater rivers and saltwater of the sea. There are 112 bays, estuaries and inlets in Victoria. Eight fish species must complete their entire life cycle in estuaries. Five of these are gobies; the others – Estuary Perch, Black Bream and River Garfish.

Salt wedge.

Salt wedges occur in many estuaries and are important in the life cycle of some animals. Salt water is denser than freshwater and, pushed inland by the tides, sits underneath fresh river water, creating a 'salt wedge' in large estuaries. Common Freshwater Shrimp (*Paratya australiensis*) depend on a stable salt wedge for their recruitment. Likewise, Black Bream (*Acanthopagrus butcheri*) and Estuary Perch (*Percalates colonorum*), which spawn in late spring, depend on the wedge to keep their semi-buoyant eggs steady below the outward flow of freshwater to the sea.[510]

Estuaries are also influenced by tides and may be closed off from the sea by sandbars when freshwater flows are insufficient to open the estuary 'mouth'. They are affected by seasonal rainfall and floods, water mixing and wave action, erosion and sedimentation. For example, mudflats and marshes on the edge of an estuary are exposed and inundated by tidal movements. Freshwater brought down by a flood can temporarily remove a salt wedge.

Coastal estuary at Thurra River, far east Gippsland. © Stephen Platt.

Bays and estuaries provide relatively safe spawning grounds for marine fish. For example, Port Phillip Bay is the major spawning site for Snapper (*Chrysophrys auratus*) and the major source of fish for the entire western coastline from Wilson's Promontory to Portland. The Gippsland Lakes probably supplies fish for the eastern coastline.[511]

The shallow, safe verges of estuaries are a favourite haunt for many wetland and wading birds seeking food or shelter.

Eels pass through estuaries on their migration.

Southern Black Bream (*Acanthopagrus butcheri*) in the Gippsland Lakes have been recorded moving up to 2,600km at speeds of 8.7km per day over 12 months. They spawn in the upper reaches of rivers and their young can be found in estuaries several months later. Each fish produces up to three million eggs per season. Juvenile bream spend the next four years in rivers, estuaries and along the coast. They reach sexual maturity at five to six years of age. Individuals living at sea must return to the rivers to complete their life cycle. Bream live up to 29 years. They are opportunistic carnivores. Some individuals are hermaphrodites with male and female characteristics. Cormorants and pelicans are their main natural predators.

Black Bream. © David Muirhead. CC BY-NC 4.0 (Int).

Australian Pelican with pouch in breeding colours. © Juliet Lowther.

Australian Pelicans egg and chicks, Mud Islands, Port Phillip Bay. © Stephen Platt.

Australian Pelicans (*Pelecanus conspicillatus*) inhabit large wetlands, estuaries and the coastline. They feed on fish, insects, crustaceans such as yabbies and shrimps, birds including Silver Gull, White Ibis, Grey Teal (which they push underwater and drown), eggs, reptiles and amphibians. Fish are often caught co-operatively with multiple Pelicans encircling their prey and driving them in to shallow water. Courtship involves males following a female, picking up objects like sticks, which they throw and catch, and mutual pouch-rippling. Breeding is timed to environmental conditions, particularly rainfall. When sufficient rain falls inland, they may travel large distances to breed. Pelicans nest communally, sometimes in colonies numbering tens of thousands. Nests are a simple scrape on the ground in sheltered sites, with difficult access to predators, such as on an island. Both parents incubate the egg on their feet. The first-hatched chick is bigger than its siblings and may kill them. The young leave their nest to form creches, up to 100 strong, for two months before independence. They may live to around 25 years.

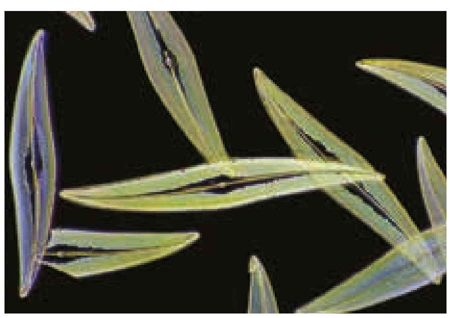
Unseen to the naked eye is the great variety of tiny planktonic organisms, along with eggs and the young of larger species, in the water column. A study of the Hopkins River catchment found that most plankton are diatoms (55 species) with some dinoflagellates (five species).[512] In salt-wedge estuaries tiny copepods, which live in the water column, drive energy production.[513]

Chapter cover: Fairies' Aprons are carnivorous herbs that catch microorganisms in underwater traps. Their presence indicates a site lacking in nutrients.

Where to see these ecosystems

- Along major rivers
- Barmah Forest
- Corner Inlet
- Edithvale-Seaford Wetlands
- Gippsland Lakes
- Gunbower Forest
- Hattah-Kulkyne National Park
- Kerang Wetlands
- Lake Albacutya
- Lower Latrobe wetlands
- Long Swamp
- Western District Lakes
- Port Phillip Bay
- Westernport Bay
- Lake Corangamite
- Pink Lakes, Murray Sunset National Park

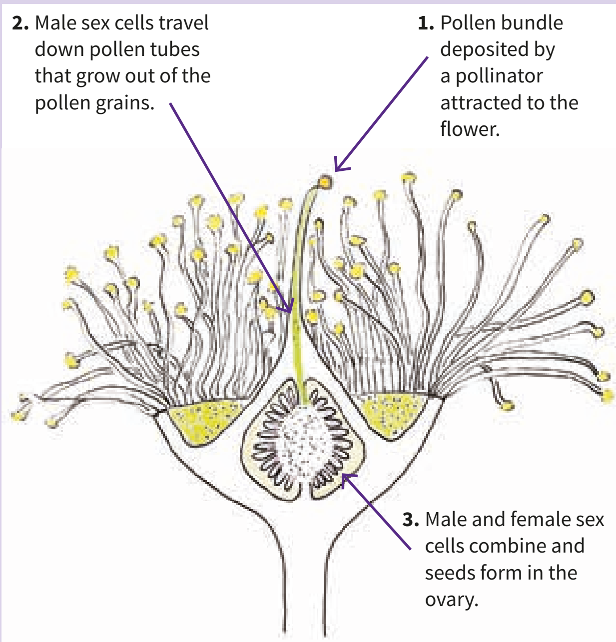
Seawater sample showing copepods with diatoms, fish eggs and a larval crab at bottom right. © Maia Valenzuela. CC 2.0 Generic.



A diatom of the genus *Pleurosigma* sp. © Frank Fox. CC SA 3.0 Germany.

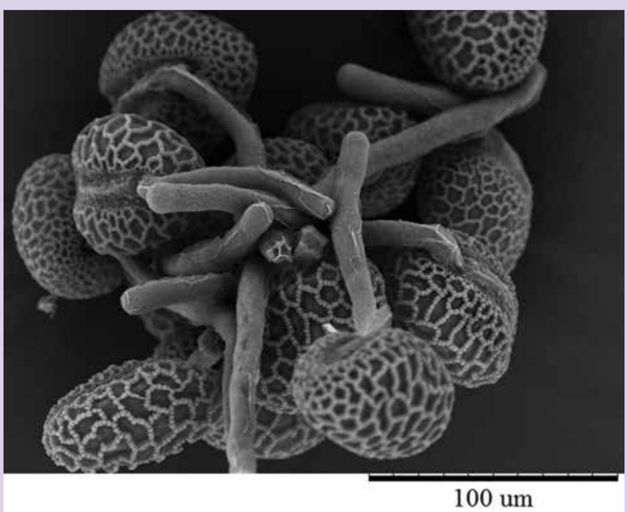
Pollination – how plant sex influences animals and ecosystems

PLANTS, BEING immobile, have a problem – how to mate with another plant and so gain the advantages of sexual reproduction. Pollen is that yellow dust that falls on the bench beneath cut flowers, that gives us hayfever in spring and, mixed with nectar to make bee bread, feeds bee larvae. Pollen contains the male sex cells. The female sex cells are located at the base of a flower in the ovary.



Pollination is the process by which pollen is transferred between flowers leading to fertilization.

The transfer can be mediated by wind, water, mammals including bats, birds, insects and other animals that visit flowers. Some plants are capable of self-pollination.



Scanning Electron Micrograph of pollen tubes growing out of Lily pollen grains. © By Neutr0nics – Own work, CC BY-SA 3.0. https://commons.wikimedia.org/w/index.php?curid=16581082

Pollinators in action © Stephen Platt (1–3), Ian McCann collection (4)

Plants that rely on wind or water as a vector for pollen movement, such as grasses, are disadvantaged by the randomness of these methods of transfer. Wind may or may not take pollen to a plant of the same type that hasn't yet been fertilised. Large quantities of pollen, and the energy required to produce it, can be wasted.

An alternative to passive transfer is to co-opt animals into service. But why would they assist? Evolution's answer has been to provide a reward for the animal pollinator as energy rich nectar. Nectar production may use up to 37% of a plant's available energy.[514] To hold and advertise this prize requires a large, colourful 'billboard' – the flower.

The flower is an evolutionary miracle that is designed to attract animals to do the job of pollination very effectively. Guided by flower type, animal pollinators can move directly from flower to flower, and ideally to a flower of the same species of plant. **Some 90% of native plants require an animal to pollinate them.**

The first flowering plants (Angiosperms) appeared around 160 million years ago and displaced conifers around 60 million years ago. There are now some 300,000 flowering species on Earth.[515] Thus, there has been an expanse of time over which specialised plant-pollinator relationships could develop.

The shape of a flower is no accident. Over time evolution has created a myriad of flower types, each designed to attract particular kinds of animal pollinators. The animal visits the flower, lured toward it by chemical smells (perfumes) and colour, and is provided with its reward of nectar. Pollen is positioned such that the visitor cannot avoid it being caught up in fur or feathers, or deposited in a bundle directly onto the pollinator.

Animals have responded in their body form to flower shapes, scents and colours. For example, Eastern Spinebills attend long tubular flowers. Their long thin bill allows them access to nectar unavailable to short-billed species of birds. This exclusive arrangement advantages the plant because the Spinebill will move on to another tubular flower, avoiding pollen losses should it visit a range of flowers. Flowers and their pollinators have thus co-evolved such that the flower suits its pollinator and vice versa.

A flower's size, structure, and colour offer a clue to its potential pollinator. For example, the colourful, long, tubular flowers, with narrow openings, of daisies attract butterflies that use their long tongue to probe deeply into the vase-like flower structure.

To complicate things, some plants are transitioning between pollinators.

Most invertebrates have been coaxed into this service. One quarter of beetles, half the flies, and all the 3,000 species of Australian native bee are flower frequenting.[516] Native bees are the most important group of invertebrate pollinators in Australia. Of course, pollen and nectar are what bees live on and the source of honey.

Some plants cheat the system by mimicking a rival flower but offering no nectar eward. The orchid *Diuris maculata*, looks remarkably like a pea plant though it is not related. Could it be mimicking pea flowers, and why? Studies have found that, unlike the peas, it does not provide a nectar reward but does have a false nectar guide (markings to orient the pollinator).[517] The colours on its flowers are very close to those on local peas, which offer a genuine reward. Orchid pollen being carried by bees is evidence that its deceptive mimicry of peas is effective.[518]

Flower mimicry. Is this Wallflower Orchid (*Diuris orientis*) mimicing the colour and shape of the unrelated pea (*Daviesia ulicifolia*) in order to deceive and co-opt its pollinator? © Stephen Platt.

The Fringed Hare-orchid is pollinated by ants. © Michael Keogh, CC-BY-NC-SA 4.0 (Int).

What about ants? Ants are extremely abundant and widespread however ant pollination is remarkably rare. This may be due to the way in which ants build nests and raise their young. They need to secrete large amounts of antibiotics to combat microorganisms. The antibiotics are toxic to pollen.[519] An exception is the Fringed Hare-orchid (*Leporella fimbriata*) which is pollinated by winged males of an ant. The orchid tricks the ant to copulate with it.

Ants do however play another important role, as 'bouncers'. Many plants (e.g., wattles) produce sweet nectar from glands other than in the flower (extrafloral). This nectar is prized by the ants which attend the gland. In return they provide protection to the plant from invertebrates that may seek to eat it. They do not provide pollination services.

In some cases, the relationship between flower and pollinator has reached high levels of intimacy. The plant deceives its male insect pollinator by emitting a chemical attractant (pheromone), by physically imitating a female insect, or both. The most well-known example is between spider orchids and ichneumon wasps. As the male insect mates with the deceptive flower, pollen becomes attached to it.

Sexually deceptive flowers have evolved on four continents. Some 160 species of Australian plants, mainly orchids, are sexually deceptive. That is, the plant emits the odour (pheromone) of a female insect to attract the male. On landing at the flower, the insect may be further deceived by its shape, colour or hairs into thinking it has found a receptive female. In attempting to mate with the flower it is dabbed with pollen and thus recruited as a pollen carrier between flowers.

One benefit to the plant is saving energy otherwise required to produce nectar. Another benefit may relate to the search behaviour of the wasp. Most generalist insect pollinators travel from flower to the next nearest flower looking for nectar. However, male wasps travel around a 15m territory in search of newly emerged females ready to mate. Up to emergence, wingless female wasps live a subterranean life. The male wasp movements, over relatively large distances, promote gene exchange with unrelated orchids (outcrossing), a genetic advantage.[520, 521]

The story gets even more complex. The Fringed Spider-orchid (*Caladenia tentaculata*) attracts a male wasp for pollination. However, the wasp life cycle relies on the larvae of scarab (Christmas) beetles, those white and grey curl grubs found in soil everywhere. The wasp lays her eggs in the scarab for the larvae to feed on when they hatch. Thus, the lives of beetles, wasps and orchids are intimately entwined. But there's more. Fire affects orchid flowering; the smoke promoting emergence of the flower from its underground tuber. Fire also affects the habitat of the wasp pollinator which prefers long unburnt vegetation.[522] Not only that, but in all these animal-plant relationships there is a synchrony in their life cycles that has a long history. The adult wasp must emerge when the flower is out and receptive. The plant must flower when the wasp is available for pollination. These intertwined lives affect what we experience of the natural world – the great flowering of springtime and after fire, the disappearance underground of many plants as they prepare for summer and fire, and so on.

If we imagine nature as a motor car, to understand how the car works we must see all the parts working together, each part with a role, and in the context of road and transport systems and manufacturing processes. Similarly, we should look at nature as a system of many-faceted relationships built up over long timespans.

To a male wasp, a Mantis Orchid (*Caladenia tentaculata*) flower looks and smells like an attractive female wasp. © Stephen Platt.

Orchid Dupe Wasp (*Lissopimpla excelsa*) on a Tongue Orchid (*Cryptostylis* sp.). © Reiner Richter. CC-BY 4.0 (Int).

Why are flowers coloured?

Flower colour is no accident of nature. Alongside flower structure and smell, it evolved to attract pollinators. The eyesight of animals varies and so flowers of a particular colour and pattern are more likely to attract particular types of animals. The advantage to the plant of selecting an exclusive animal pollinator is reduced wastage of pollen.

Mammals and birds can see from a distance and are attracted to sturdy red or yellow flower clusters that can provide the large reward their body size and level of activity demands (e.g., Red Ironbark, many Banksias).[525] Pollination by birds is called ornithophily.

Bees cannot see red but they can see blue, green and ultraviolet. Many flowers have ultraviolet patterns (not visible to humans) that indicate to the bee where the nectar and pollen can be found. Due to their compound eye, bees do not see very clearly until up close. They thus rely on smell to find a flower then switch to sight as they get up close. In comparing bee and bird pollinated yellow flowers, it appears that bees are attracted to those with clear ultraviolet patterns such as 'egg and bacon' pea plants (e.g., *Daviesia* spp., *Pultenaea* spp.).[526]

Flies have an innate preference for certain types of yellow and cream-green colours, such as wattle flowers.[527] Small white or pink flowers, perfumed at night, may attract moths.

Thus, flower colour is aligned with the spectrum of light best seen by the pollinator and flower structure is closely aligned with the physical characteristics of the pollinator.

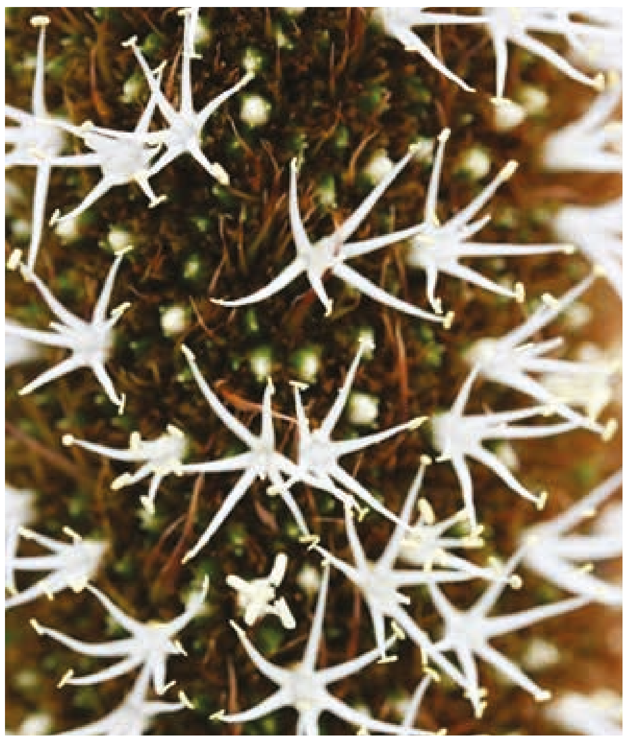
Common Correa (*Correa reflexa*) is bird pollinated.

© Stephen Platt.

If you wait by a native pea flower until its insect pollinator, such as a bee, comes along you will understand its structure. The flat petals are the landing pad, backed by a bright billboard of vertical petals that attract attention. A bright colour shows where the nectar is found and serves to 'park' the insect in just the right spot because, as it settles down to drink, the platform petals slide sideways and down to expose filaments holding the pollen which is dabbed underneath the insect.

The native pea, Happy Wanderer (*Hardenbergia violacea*).

© Stephen Platt.



Flowers of Austral Grass-tree *(Xanthorrhoea australis)*.

© Stephen Platt.

Edith Coleman (1874–1951)

EDITH COLEMAN'S daughter had made an unusual observation – a wasp was seen backing into an orchid. They watched further and other wasps were seen to do the same thing – but why? Over several seasons Edith carefully dissected the flowers and had the wasps identified as an Ichneumon wasp (*Lissopimpla excelsa)*. They turned out to all be males. A droplet of liquid left inside the flower was identified as sperm belonging to the wasps. Edith had confirmed a most remarkable relationship in which certain orchids (*Cryptostylis* spp.) mimic the structure and emit the scent of female wasps, tricking male wasps to mate with them whilst at the same time being daubed with orchid pollen which they then transmit to other orchids facilitating pollination.

Edith Coleman was a dedicated naturalist who pursued her interest in many directions – echidnas, mistletoe, stick insects, spiders and birds – over several decades. She was the first woman to be awarded the Australian Natural History Medallion in 1949, two years before her death.[523,524]

Edith Coleman in 1949. Source: Victorian Naturalist, Vol.67, p.99, Sept 1950. Public domain.

Getting to know our invertebrates

1. Cuckoo Wasp (*Stilbum cyanurum*, only one record from Victoria). © Ken Walker CC.
2. Glow-worm (*Arachnocampa otwayensis*, the larvae of a fly. It uses light to attract prey to dangling threads of mucus). © Reiner Richter. CC-BY 4.0 (Int).
3. Diamond Weevil (*Chrysolopus spectabilis* Larvae feed on roots, and adults on the leaves, of wattles). © Donna Tomkinson. CC-BY 4.0 (Int).
4. Dampwood Termite (*Porotermes adamsoni*). © Ken Walker., CC
5. Yellow Monday (yellow form of Greengrocer) Cicada (*Cyclochila australasiae*). © Stephen Platt.
6. Fly (*Amenia* sp.). © Stephen Platt.

Getting to know our invertebrates

Invertebrates	Taxa	Threatened	%
Terrestrial (native)	12,248	76	0.62
Aquatic (native)	1,957	12	0.61
Marine (native)	609	11	1.81
Invertebrates (introduced)	6		
Total (native invertebrates)	14,794	99	0.67

N.B. This table is an underestimate of actual numbers of taxa due to our general lack of knowledge of the invertebrate fauna.

INVERTEBRATES ARE the most numerous animals on Earth. Some 90% of all animal species are invertebrate. They occur in every environment. Australia has an estimated 275,000–300,000 terrestial invertebrate species. Many species are unique to our continent including over 80% of all the cicadas, leafhoppers, true bugs and ants.[528] Only about 15% have been formally described.

In Victoria (2009), 99 taxa are listed as threatened but this is an underestimate as many types remain undiscovered, unstudied or undescribed. As an indication of the diversity of invertebrates, there are around 119 butterfly (Vic.), 81 dragonfly and damselfly (Vic.) and 1,275 ant (Aust. in 1999) taxa.

Without invertebrates it would be impossible for humans to survive. They pollinate 80% of our cultivated food plants and 65% of all plants, are prey and predator keeping pest species in check, are recyclers and decomposers that contribute to ecosystem health. Invertebrates such as beetles (e.g. weevils), bugs (e.g. seed bugs), wasps, ants, thrips and some moth species feed on seeds. Others, particularly ants, are involved in seed dispersal. Whilst some species may be annoying or dangerous, their overall contribution literally keeps life functioning.

Lying in wait, two spiders stake out this flower waiting for a pollinator to arrive. © Stephen Platt.

Types

At the Group level there are Cnidarians (corals, hydras, jellyfish, Portuguese Men-of-war, sea anemones, sea pens, sea whips, sea fans), Platyhelminths (flatworms), Molluscs (snails, slugs, limpets, whelks, conchs, periwinkles, clams, oysters, mussels, scallops, cockles, shipworms etc.), Annelids (segmented worms), Arthropods (crustaceans, insects, spiders, millipedes, scorpions etc.) and Echinoderms (starfish, sea urchins, sand dollars, sea cucumbers, sea lilies) occupying terrestrial, freshwater and marine habitats.

Molluscs are the largest marine group (~85,000 species worldwide) and insects are the most diverse on land (~250,000 species).[529]

The wingless female Bluebottle is often mistaken to be an ant. © Snoozymama. CC-BY-NC 4.0 (Int).

I still recall the scream of a fellow student who made contact with a female Bluebottle (*Diamma bicolor*) in the remnant native vegetation at the back of my school. Despite looking like an ant, it is in fact a solitary female parasitic wasp with a powerful sting. She runs about with her abdomen erect looking for young mole crickets. The unfortunate quarry will be paralyzed and an egg laid on it. Her larva will feed on the cricket. The winged male visits flowers for nectar and is an important pollinator (they are also called 'flower wasps'). Significant differences in the anatomy of males and females (sexual dimorphism) is not uncommon in the invertebrate world.

Male thynnine 'flower' wasp (*Diamma bicolor*) investigating a spider orchid. © Ken Walker. CC-BY-NC-SA 4.0 (Int).

An endangered Otway Black Snail (*Victaphanta compacta*). © John Eichler. CC-BY-NC 4.0 (Int).

The critically endangered Western Swamp Crayfish (*Gramastacus insolitus*). © David Paul, Museums Victoria. CC0.

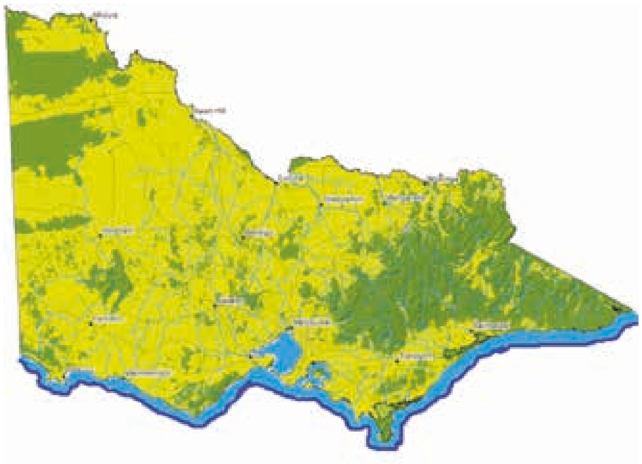
The regionally extinct Metallic Carpenter Bee (*Xylocopa aeratus*). © Tim Leach, CC-BY.

The coast – where land meets sea

Sea stacks and cliffs of sedimentary rock fill this view of western Victoria's coastline. Here two vastly different ecosystems – land and sea – meet. © Stephen Platt.

The coast – where land meets sea

***HEDGED BY** salt, hoodies, flying across the globe to breed, the fairy separation rate, a parrot that crosses Bass Strait just to feed on saltmarsh, making the most of infertility, eating itself to death – the coast is a border like no other, separating vastly different ecosystems, yet still supports a variety of lifeforms.*



Victoria's coastline and marine waters to an offshore territorial limit of three nautical miles.

Historic map used to delineate public land along the Victorian coastline. Source: Victorian Government Gazette 27 May 1881.

Introduction

THERE ARE some decisions and pieces of legislation that we take for granted but that profoundly change our lives – free and secular public education, public land reserves along waterways and access to the beach are examples. With great foresight, public lands along the coast were set aside from sale so that they were permanently reserved for public use via two pieces of Victorian legislation in 1879 and 1881.[530] Thus, most of the Victorian coast was reserved for everyone's enjoyment and, as a consequence, nature was largely protected from clearance for development.

1389 May 27, 1881.

LANDS PERMANENTLY RESERVED FROM SALE.

IN pursuance of the provisions of *The Land Act* 1869 (33 Vict. No. 360, § 6 and 8), the Governor in Council has reserved from sale, *permanently*, the lands hereinafter referred to viz.:—

Reserved by Orders of 23 May 1881.

Sites for Public Purposes, Nos. 1 to 20 inclusive. See *Gazette* of 11 February 1881.

Sites for Public Purposes, Nos. 21 to 44 inclusive. See *Gazette* of 25 February 1881.

Sites for Public Purposes, Nos. 45 to 62 B inclusive. See *Gazette* of 4 March 1881.

Sites for Public purposes, Nos. 62 C to 70 B inclusive. See *Gazette* of 18 March 1881.

R. RICHARDSON,
Commissioner of Crown Lands and Survey.

Lands and Survey Office,
Melbourne.

Extract from the Victorian Government Gazette, 27 May 1881.

The coast is where land meets sea and is probably the point of greatest contrast across an ecological boundary.

The length of Victoria's open coast and major bays and inlets is 2,565 kilometres. There are 19,212ha of coastal saltmarshes, 5,177ha of mangroves and 3,277ha of estuarine wetlands in Victoria.[531] Some 94% of the coast is Crown (public) land and 27% is in coastal reserves.[532]

Ecosystem outline

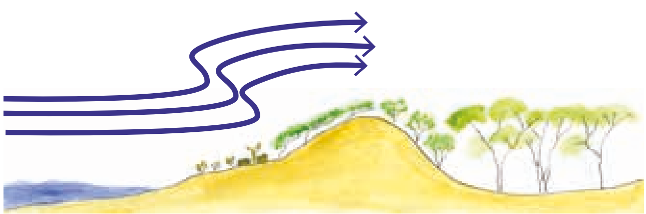
KEY INFLUENCES on plants and animals along the Victorian coast include:

- **The unstable nature of sand dunes** that form the interface with the sea. Sand is both poor in nutrients and in its water-holding capacity. In some areas, generally where vegetation has died, wind excavates depressions (blowouts) and the resulting dunes become unstable and roll inland.

Unstable dunes move inland to cover vegetation at Thurra River in Gippsland. © Stephen Platt.

- **Salt-laden, strong winds and lack of shade and water at the foreshore.** Salt can kill new plant shoots, affect water uptake by plants and alter soil chemistry disadvantaging some plants whilst favouring others. Coastal winds can reach gale force and are capable of uprooting tall trees and shrubs, whilst the salt they carry prunes growing tips on plants into hedged forms and dehydrates plants. Wind and tide together act to move seawater to its uppermost inland limit. Water availability to plants is often limited and poor due to the sandy nature or shallow depth of the soil.

Victoria's coastline and marine waters, which extend to an offshore territorial limit of three nautical miles. © Stephen Platt.



Trees shelter behind the dunes from sometimes gale-force wind and king tides.

- **The erosive capacity of ocean waves.** Cliffs form along some sections of the coast and their collapse removes vegetation and soils. Due to the predominant south-westerly winds, this is particularly the case in western Victoria. Resistant rock forms reefs that may be underwater at high tide and exposed at low tide. The beach may be formed of sand, gravel or larger rounded stones.

Eroded cliffs and submerged reef platforms at Bridgewater Bay. © Stephen Platt.

- **The influence of the waters of Bass Strait**. The East Australian Current carries warm water from tropical areas whilst the Circum-Antarctic Western Current has cold polar origins. As a result of their influence, which varies throughout the year, coastal environments differ markedly. For example, the coast of East Gippsland has a Mediterranean-like climate of warm summers and mild winters. Increased rainfall due to warmer ocean temperatures sustains inland patches of rainforest.

Beach sand can be derived from coastal rocks, in some instances containing quartz (silicious) or be of calcareous origins (made of calcium carbonate derived from crushed sea shells). The latter can dissolve and harden to 'cement' together the sand in dunes. Some calcareous dunes on the Victorian coast are ancient (thousands of years old) and were formed in times of higher sea level.

Sand-binding species such as Spinifex (*Spinifex hirsutus*, not to be confused with arid zone 'spinifex' which is *Triodia* spp.) and tussock grasses help to stabilise the primary (closest to the sea) sand dunes thus enabling establishment of grasses, herbs and shrubs immediately inland often backed by taller shrubs such as banksias (*Banksia* spp.), coastal wattles (*Acacia* spp.), paperbarks (*Melaleuca* spp.), tea-trees (*Leptospermum* spp.) and beard heaths (*Leucopogon* spp.).[533]

Reptile eggs exposed by a drifting sand dune. © Stephen Platt.

Leaf types are generally designed to reduce water loss – small and hard, fleshy (e.g., Beaded Glasswort [*Salicornia quinqueflora*]) or non-existent (e.g., Drooping Sheoak [*Allocasuarina verticillata*]).

A large body of water holds heat better than land and so temperatures along the coastline are always moderate compared with inland. Frost is infrequent but heavy dew is common.

Fire in coastal vegetation is highly variable and depends on the type of vegetation – dune, scrub, woodland, heath. There is some fire protection provided by the succulent, salt-tolerant nature of some coastal plant species.

Nevertheless, fire influences coastal vegetation. Over the last 200+ years at Ocean Grove, the vegetation has changed from an open grassy woodland of eucalypts and banksias (e.g., Silver Banksia *Banksia marginata*), to an open scrub of Golden Wattle (*Acacia pycnantha*) and then to a closed scrub of Drooping Sheoak (*Allocasuarina verticillata*). She-oaks were not even recorded in an 1894 census and have increased from perhaps less than 20 trees/ha in the early 1800s to over 3,000 trees/ha today. The increase in Sheoaks has been interpreted as due to the long-term absence of fire. The historical abundance of Golden Wattle may have followed the end of burning by Aboriginal people (wattles being stimulated to germinate by fire).[534]

Beaches, lagoons, mudflats and islands

A BEACH is a very harsh environment of salt, strong winds, sun, sand and tidal inundation. No plants manage to grow under these extreme conditions and it appears that few animals live on a beach. But that's incorrect. Beaches are alive with animals including worms that live buried in the sand, crabs that burrow and wracks of seaweed that teem with invertebrates. There are the birds that feed on them – Sooty and Pied Oystercatchers (*Haematopus fuliginosus, Haematopus longirostris*), with their long probing beaks, suck out worms on the receding tide; Hooded Plovers (*Thinornis rubricollis*) scurry after small insects and White-bellied Sea Eagles patrol the shore for carrion washed in from the sea.

The Amphipod *Hippomedon denticulatus* grows up to 15mm long. © Michael Marmach CC-BY-NC.

Hooded Plover. © J J Harrison. CC SA 3.0 Unported.

Hooded Plovers lay their well-camouflaged eggs in a simple scrape on the beach where they are exposed to the elements and predators. © Stephen Platt.

On the exposed beach, camouflage helps to keep this Oystercatcher chick safe. This also explains the fairly drab, 'mottled sand' colour of many wading birds. © Juliet Lowther.

Beach-washed shells are a clue to the local marine environment. Scallops are typical of muddy substrates, whilst other shells seen here are mainly of rocky reefs. Pipies (e.g., *Donax deltoides*) use their foot to burrow into sand – adults sub-tidally, juveniles in the intertidal zone – and live up to five years. The small hole in the pipi shell at bottom left was made by the rasping 'teeth' of a predatory starfish.
© Stephen Platt.

Pacific Golden Plover. © Leo. CC-BY-NC-SA 4.0 (Int).

Birds find the coast particularly attractive with its combination of food concentrated by the tide and relative safety. Thirty-seven species of migratory shorebirds feed on the mudflats, lagoons and estuaries of Victoria's coastline.[535]

In a feat of endurance rivalled by no other animals, migratory wading birds breed thousands of kilometres away. For example, Pacific Golden Plover (*Pluvialis fulva*) and Red Knot (*Calidris canutus*) migrate to the high arctic tundra while Latham's Snipe (*Gallinago hardwickii*) migrates to Japan. These birds fly south to Victoria to avoid the severe northern winter. Breeding in the arctic takes advantage of the northern hemisphere summer and its abundant invertebrate food supply that is ideal for rearing young. Migratory wader's 'ecosystem' operates at a global scale. Hitchhikers, including invertebrates and seeds, can travel with them, hidden in their blanket of feathers or in the gut, over these vast distances.

Migratory shorebirds can fly non-stop for days or weeks. Not only that, they can sleep 'on the wing' with half or all their brain asleep.[536]

Travellers on the highway from Melbourne to Geelong will pass by the Western Treatment Plant, where Melbourne's sewage is processed. Its other use is as an immensely important refuge to huge numbers of migratory shorebirds.

Australasian Gannets (*Morus serrator*) feed out at sea, soaring to 10m before folding their wings and plunging into the waves after open sea (pelagic) fish. They breed in dense colonies on islands, artificial structures and on mainland promontories.

Twenty million plus Short-tailed Shearwaters (*Ardenna tenuirostris*), also known as 'muttonbirds', breed around Bass Strait. In places, the coastal ground is riddled with their breeding burrows. Remarkably, they travel to the Antarctic ice edge to feed, then migrate across the Pacific and return along the eastern Australian seaboard arriving in Victoria in September.

They are so adept at swimming, that it is easy to forget that the Little Penguin is a bird. The abundance of marine life as a food source has influenced a number of originally terrestrial bird types, including penguins, cormorants, petrels, shearwaters, gannets and albatross, to adapt to either swimming or diving. However, they remain tied to the coast for breeding.

For over 45 years Little Penguins (*Eudyptula minor*) have been studied at Phillip Island where they nest in burrows among the dunes. Tracking has revealed that they feed within 50km of their burrow, some entering Port Phillip Bay. Hunting trips last for two days in good seasons and longer in poor seasons. Red Cod (*Pseudophycis bachus)*, Barracouta (*Thyrsites atun)*, Warehou (*Seriolella brama)* and Anchovy (*Engraulis australis)* comprise over 90% of the diet. Pilchards were also prominent until 2000 when there was a mass mortality event. A wide range of other small or juvenile fish and squid are also eaten[537] Living together in a colony and group hunting may benefit Little Penguins in being able to detect prey.[538] The onset of breeding varies from year to year.[539] In Victoria, one-to-three eggs (usually 1–2) are laid from July to December. Males guard females in the burrow until the first egg is laid. Both parents share incubation duties. The between-season separation rate is 28%, which is high among penguins. Unfaithfulness also seems to occur, with different partners being seen in burrows one third of the time.[540,541,542] Both parents feed the young chicks. Tiger Snakes (*Notechis scutatus*) may take chicks and blue-tongued lizards may take eggs. At sea, adults are preyed on by seals.

Australasian Gannet. © Anna Lanigan. CC-BY-NC 4.0 (Int).

Short-tailed Shearwater. © Leo Berzins. CC-BY-NC-SA 4.0 (Int).

Little Penguin. © J J Harrison. CC SA 3.0 Unported.

Australian and New Zealand Fur Seals haul themselves onto rock shelves at Cape Bridgewater where they can enjoy the sun and are safe from predators including Great White Sharks. © Stephen Platt.

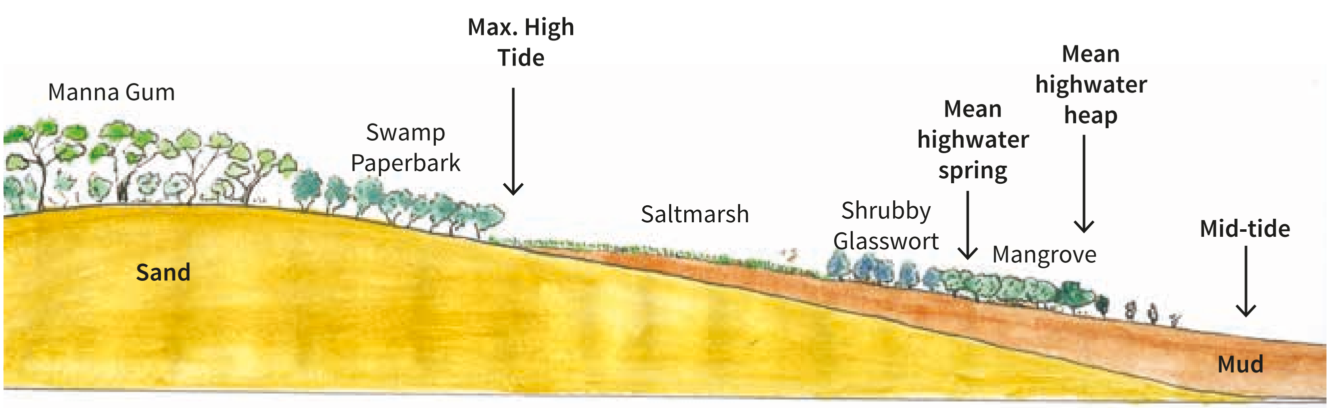
Australian Fur Seals (*Arctocephalus pusillus doriferus*) primarily feed on squid, shoaling fish and octopus. Males establish breeding territories at around 11 years of age and mate with a number of females. The average male tenure is just 1.8 seasons. Lifespan is around 20 years.

Mangroves and saltmarsh

IF YOU like to fish for, or eat, flathead, bream, whiting or flounder then you should like mangroves. Victoria has over 5,000ha of Grey Mangrove Forest (*Avicennia marina subsp. australasica*) and one of the ecological roles it performs is provision of nursery areas for young fish. Mangroves occupy sheltered, muddy bays and estuaries such as Westernport Bay and Corner Inlet. They can tolerate high levels of salt and their roots obtain oxygen through specialised structures called pneumatophores that poke out of the mud into the air. Their fruit germinates on the plant before falling into the mud. Other ecological roles of mangroves include trapping silt and so contributing to clear seawater needed by seagrasses and kelp, providing habitat for a range of animals and protecting coastlines against erosion.

Grey Mangrove in Westernport Bay. © Stephen Platt.

Distinct patterns of coastal vegetation, often running parallel with the coast, are a result of the influence of salt water, elevation and substrate; and plant species' capacity to adapt to the limits they set. Mouth of the Snowy River. © Stephen Platt.



Coastal zonation, as found in Westernport Bay, is explained by seawater, tides and substrate. (After Bird 1975). Saltmarsh extends as far inland as the highest tide. © Stephen Platt. Vertically exaggerated.

Above: Rounded Noon-flower (*Disphyma crassifolium* subsp. *clavellatum*) attracts mating Plague Soldier Beetles (*Chauliognathus lugubris*). © Stephen Platt.

Below: Beaded Glasswort (*Sarcocornia quinqueflora*) saltmarsh on French Island. © Stephen Platt.

Why has this area of vegetation, just inland from the sea at right, died? A storm may have brought seawater over the foredune and then, concentrated by the sun, salt levels have exceeded the tolerance of the shrubs that grew here.
© Stephen Platt.

Saltmarshes occupy over 19,000ha of Victoria and consist of a variety of salt-tolerant shrubs, grasses and succulents. They are often found in association with mangroves and occur on intertidal mudflats.

Floristically, saltmarsh is the least diverse ecosystem in Victoria. Grey Mangroves (*Avicennia marina subsp. australasica*), Beaded Glasswort (*Sarcocornia* spp.) and other glassworts (*Tecticornia* spp.) may dominate the vegetation.

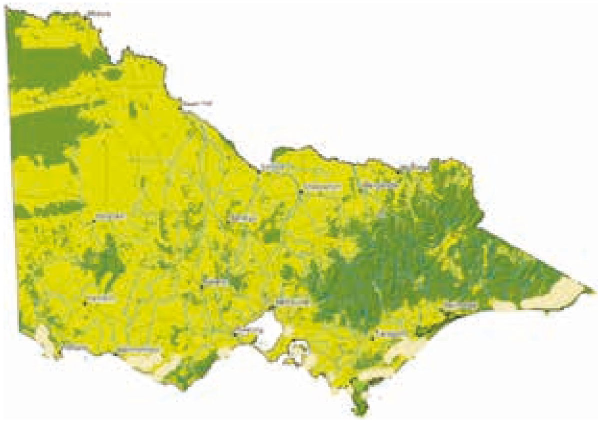
Most of the birds in saltmarsh are common coastal and wetland species. Two species are saltmarsh specialists – the Orange-bellied Parrot (*Neophema chrysogaster*) and White-fronted Chat (*Epthianura albifrons*).

The endangered Orange-bellied Parrot feeds in saltmarshes along the Victorian coastline but breeds in Tasmania, requiring a twice-yearly crossing of Bass Strait. Whilst this seems a strange and hazardous journey, it wasn't always so. Victoria and Tasmania were once connected when sea levels were lower, around 12,000 years ago.[543] As Bass Strait formed, presumably parrots learnt to cross the sea gap, which gradually grew wider.

The Orange-bellied Parrot is a saltmarsh specialist.
James Bailey. CC BY-NC 4.0 (Int).

White-fronted Chat. © Stephen Platt

Coastal Heathlands



Approximate location of coastal heathlands in Victoria.

Heathy woodland at Anglesea. The Anglesea heaths are very diverse with over 911 native vascular plant taxa having been documented including 124 orchid taxa.[546] © Stephen Platt.

THE PROBLEM that all heathland plants must resolve is overcoming the very low nutrient levels in the soil on which they grow, which is largely comprised of sand. They have three primary strategies to cope. Firstly, grow slowly and not too big; next, gather what nutrients you can; and lastly, store nutrients. Low stature means less overall demand for nutrients and, combined with relatively slow growth, partially solves the low nutrient problem. Heathland plants also have ingenious ways of extracting the nutrients that do exist. Some species (*Banksia, Hakea, Grevillea* species) can generate dense clusters of fine roots, covered in root hairs, in pockets of high nutrients. Other species, particularly shrubs and small trees, form associations with fungi. The host plant provides food for the fungus whilst the fungus collects nutrients for its host by spreading its threadlike hyphae though the sandy soil. Another partnership used by bush peas, wattles and hakeas involves an association with soil bacteria that live in nodules in the host plant's roots while extracting nitrogen from the air. Then there are those species that eat insects for their nutrients (sundews, bladderworts), or parasitise other plants (e.g., *Cassytha*). Lastly, many heathland species have storage organs such as underground tubers and corms (e.g., orchids), and leaf bases (sedges)[544] which allow storage of nutrients for future use.

The origin of the word 'heathland'

*"Heathland is one of the oldest recognised ecosystems in the world. The name was first applied to the treeless vegetation of Europe where Heather (*Calluna vulgaris*) and the spiny pea, Gorse (*Ulex europaeus*), often make up the bulk of the vegetation. The male and female names Heath and Heather are derived from the ecosystem and the term Heathen was originally coined to represent those people who lived in Heathland away from the major townships and hence shunned mainstream Christianity."*

Source: Viridans[545]

Grass Trees (*Xanthorrhoea australis*) flowering after the Ash Wednesday bushfires. © Stephen Platt.

What happens to heathland vegetation after a major fire? At Anglesea after the 1983 Ash Wednesday bushfire, all pre-fire plant species reappeared within two years; one third of species relied on seed alone, all others could resprout. Half of the species flowered in the first year and almost all by year three. There were more species present in the early years after the fire than as the years passed (presumably some were now only present in the soil seedbank or were capable of rapid dispersal). By year ten, only 60% of the taxa remained visible. Herbs gave way to shrubs. The gums took seven years to re-establish their leaf canopy.[547] A plant that was thought to be extinct, now called Wrinkled Buttons (*Leiocarpa gatesii*), was rediscovered by Mary White, a local naturalist. Sixty years previously it had been recorded after a large fire event.

Some terrestrial orchids are stimulated to flower after fire. Chemicals produced by the fire and contained in smoke (particularly karrikinolide) infiltrate the soil where orchid tubers may lie dormant. This initiates mass flowering. Such a strategy may favour attracting pollinators, with large numbers of highly visible flowers clustered together, whilst also favouring seed germination in the open, less competitive, post-fire environment.[548]

Fire in heathlands is frequent (12–45 years) and usually kills all above-ground vegetation but, significantly, not root systems.

Ground Parrots (*Pezoporus wallicus*) are heathland specialists. They feed on the seeds of a range of plants and, in dense heathland vegetation, build a nest of fine sticks and grass forming a shallow bowl on the ground. Several studies have shown that Ground Parrots are most abundant when the post fire vegetation is vigorously producing seeds, which initially increases then declines as the vegetation ages. [549,550,551, 552]. Hence, a patchy mosaic of different post-fire vegetation age classes is needed to support this species over time. Early growth stages provide for a continuous food supply and long unburnt vegetation is needed for breeding.

Wildlife species vary in their responses to fire. A study of honeyeaters in mountain heathland found that their abundance increases rapidly post fire for the first ten years and then remains at this level for at least 39 years.[553] A small population of Southern Brown Bandicoots (*Isoodon obesulus*) inhabiting heathland vegetation decreased by 65% after a fire. One died during the fire and three were killed by predators after the fire. Survivors shifted to unburnt habitat within their home range.[554]

The Long-nosed Potoroo (*Potorous tridactylus trisulcatus*), which is widespread in coastal areas and the Grampians, has a very sensitive nose. It uses this ability to find underground fungi (sporocarps of hypogeal fungi) of many species, its primary food.[555] There may be 20,000 to 180,000 truffles (sporocarps) per hectare in forest soils.[556] Potoroos have an enlarged fore-stomach full of microbes. This allows them to obtain more nutrition from eating fungi than other wildlife species.[557] Bush Rats (*Rattus fuscipes*) also eat underground fungi year-round but predominantly in autumn and winter.[558] Both species are important dispersers of fungal spores throughout the forest. The fungi that develop from these spores associate with the roots of forest trees and assist with their nutrition. Thus, forest health is intimately linked to the presence of Potoroos and Bush Rats.

Red-beaks (*Pyrorchis nigricans*), an orchid, is stimulated to flower following fire. © Stephen Platt.

Many heathland plants develop woody fruits (serotiny). They protect the seed from fire and release it either post-fire, where it will benefit from surface nutrients, or on the death of the plant, often following drought. Strong serotiny correlates with low nutrient soils and frequent fire.[559] © Stephen Platt.

Ground Parrot. © Tas47. CC BY-NC 4.0 (Int.).

Long-nosed Potoroos and forest trees have a special relationship. © Brett Vercoe CC-BY-NC 4.0 (Int)

Long-nosed Potoroo with well-developed pouch young. © Alan Robley, DELWP. CC 3.0 (Aust.).

These ball-shaped, empty shells contained a truffle-like fungus that proliferated after the Gippsland fires in 2020. They have been dug up and eaten by a potoroo or bandicoot (note the pointed, cone-shaped hole which is different to the rounded hole made by an introduced rabbit). © Andrew (Andy) Murray.

New Holland Mouse. © Doug Beckers. CC SA 2.0 Generic.

Antechinus species, native Bush (*Rattus fuscipes*) and Swamp Rats (*Rattus lutreolus*), are common in heathland. Up to 21 Agile Antechinus (*Antechinus agilis*) per hectare have been recorded in heathland at Anglesea.[560] Late winter and early spring sees adult males disappear from the population as they 'die off' annually, to be replaced by the next generation.

In the Grampians heathlands, small mammal abundance is affected by both time-since-fire and rainfall. Rainfall affects the rate of recovery after fire. Small mammals are more common in areas that have greater productivity and phytofall, presumably because more food is available.[561]

At Cranbourne, the endangered New Holland Mouse (*Pseudomys novaehollandiae)* and endangered Southern Brown Bandicoot are found in dry heaths.[562]

The Rufous-bellied Pademelon (*Thylogale billardierii*) was common in coastal scrub prior to its mainland extinction following European settlement.

Moonah and Tea Tree Woodlands

MOONAH (*MELALEUCA* *lanceolata*) and Coastal Tea-tree (*Leptospermum laevigatum*) woodlands occur on calcareous dunes along the coast including on the Mornington Peninsula and Great Ocean Road. You may have walked through them on the way to the beach, sand underfoot, amid the twisted trunks.

They have changed in character due to urbanization, with only remnants remaining. Somewhat surprisingly the bird fauna in larger (>2ha) remnants remains largely native.[563,564]

The Eastern Pygmy-possum (*Cercartetus nanus*) lives in a range of habitats with a diverse shrub layer, particularly containing *Banksia*, which is a reliable source of nectar and pollen.[565] These tiny possums move about to follow plants in flower, especially in spring when *Banksia* stops flowering.[566] The possum shelters in any suitable hole including tree cavities, stumps, grass tree skirts and holes in the ground. Young are born in nests lined with fresh leaves. Nest sites are changed frequently probably to avoid predators and manage disease and parasites. Females give birth once a year, between February and May, to three or four young. They can produce up to 40 young in their three-year lifetime. This tiny possum is mainly nocturnal and, when temperatures fall in winter, enters torpor and hibernation. It uses its brush-tipped tongue to feed on nectar but will switch to fruits, especially beard heath (*Leucopogon* spp.), when nectar supply is limited.[567]

Eastern Pygmy Possum. © Beth Boughton. CC BY.

Coastal Tea Tree at Wilson's Promontory National Park. © Stephen Platt.

Juvenile Eastern Pygmy Possum. © Howard Jones. CC BY.

Coastal Manna Gum and Messmate Forests

MESSMATE (*EUCALYPTUS* *obliqua*) is a common gum tree along the Otway coast and in the wet mountain forests of Victoria. In the understorey of Messmate coastal forests lives the Rosy Hyacinth Orchid (*Dipodium roseum*), which is leafless and perennial. It cannot photosynthesise, so how does it obtain food? Nutrients are supplied via association with a fungus living in the soil (mycoheterotroph). The fungus lives on decaying organic matter.

Medium-sized, white barked Coastal Manna Gum (*Eucalyptus viminalis* ssp *pryoriana*) trees also occur along the coast and are a favourite food tree of the Koala.

A great deal can be learnt about the bush by listening, particularly at night. In suitable lowland forest and woodland habitat, the first indication you might get of Koalas (*Phascolarctos cinereus*) being present is a loud snoring sound called 'bellowing'. This is the male advertising his territorial claim and seeking to attract local females.

Perched high in a tree limb, adult Koalas have few predators to be concerned about although historically Dingo (*Canis lupus dingo*), fire and Aboriginal hunting helped to regulate Koala populations. Juvenile Koalas are at risk from Powerful Owls and Wedge-tailed Eagles.

The eucalyptus leaves they dine on are not particularly nutritious and contain high levels of toxins. It is not true that Koalas only eat one type of gum leaf. They will readily eat from a range of eucalyptus species, which varies throughout their distribution, and select the younger leaves of trees that contain fewer toxins. Most of the feeding is done during the first half of the night.

Koalas are highly territorial and may stay in the same patch of bush for many years, marking it with scent from a gland on his chest and occasionally making short trips outside its boundary. In one instance, a relocated Koala made its way back several kilometres to its usual home range.

Females breed from two up to 13 years of age and may live to 18 years. Males live more hazardous and shorter lives. One of the hazards is fighting other males for access to females. At birth, a Koala weighs just half a gram. It will eventually weigh up to 12.5kg or 25,000 times its birth weight.[568] Usually, just one young is born and, with the devoted attention of its mother, has a high chance of surviving to wean at around one year of life.

The modern story for Koalas is a tragic one. Territorial but lacking natural regulators, isolated Koala populations can increase to the point where their feed trees are continuously stripped of leaves and die. Loss of food leads to a mass death of the resident Koala population. This scenario has played out many times in relatively small patches of bushland.

Rosy Hyacinth Orchid at Parker Hill, Cape Otway. © Stephen Platt.

Koala. © David Iliff. CC SA 3.0 Unported.

Could you consider eating a Koala? William Brodribb (1839) recounted that an Aboriginal named Charley Tara had caught Koalas to feed Count Paul Strzelecki during his explorations in west Gippsland in 1840.[569] Horace William Wheelwright (1862, p39) wrote that "the flesh is eatable, not unlike that of the northern bear in taste. It is considered a delicacy by the blacks." In the early 1900s, commercial hunting for Koala skins was widespread.

Nowadays, Koalas are internationally regarded as symbolic of 'cuteness' and protected from hunting by law.

A truck load of 3,600 Koala skins which were obtained by a party of hunters in thirty days in the Clermont area during the last open hunting season in Queensland, 1927.

Source: John Oxley Library, State Library of Queensland, Australia. Negative number: 18937. Record number: 21220132070002061.

Chapter cover: Cliffs and rock stacks indicate that the coast is eroding at this point. The beach is unsuitable for beach-nesting birds. The little terrestrial vegetation that is present atop the cliffs is short and salt-tolerant due to the prevailing winds, infertile soils and extreme dryness. Isolated islands, such as the sea stacks, may offer refuge and breeding sites for seabirds. Reef platforms exposed by the tides daily support a small range of algae.

Under the sea – our alien neighbours

A garden of sponges. Where are we? Why do sponges dominate here?

Under the sea – our 'alien' neighbours

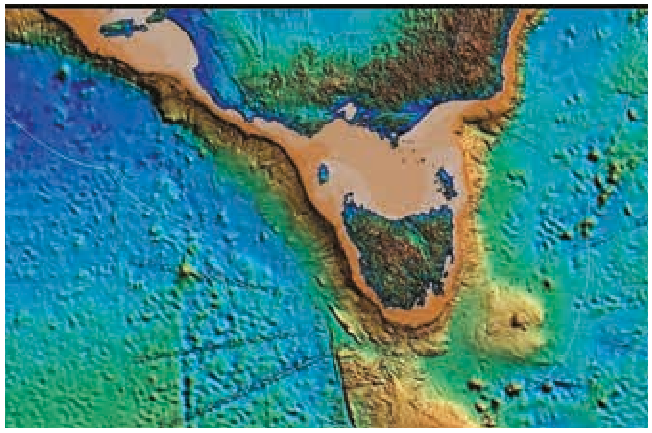
***A SEA-GOD'S** necklace, nature's strongest material, a bite that makes humans appear dead when they are not, eating its siblings before they are born, an egg that looks like seaweed, losing an arm during sex, giving up on shells, a bone that's not bony, congregating to get undressed, eating stingers, glowing in the dark – it's a very different world in Victoria's marine ecosystems.*

An alien world

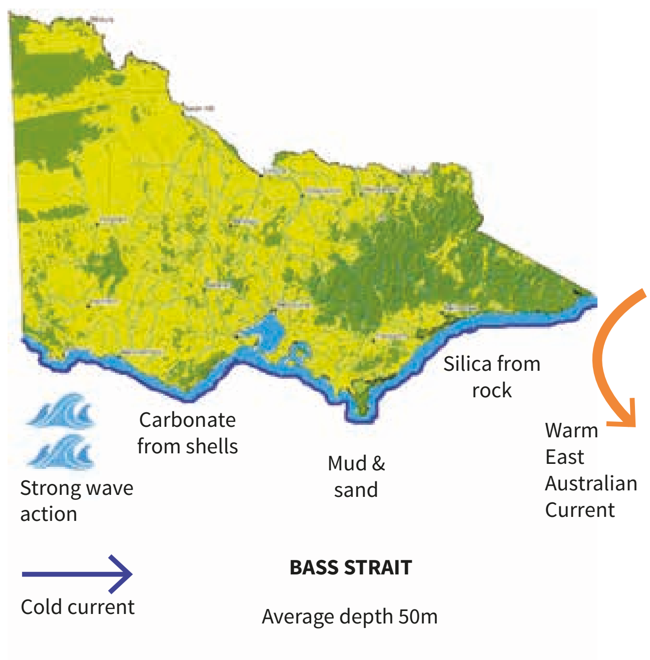
Marine	Taxa
Algae	531
Fish	1043
Invertebrates (crustacea, echinoderms, sea fans, sponges, ascidians, mussels)	366
Penguins	9

Marine diversity as currently recorded on Victoria's Biodiversity Atlas. This is likely to be a significant underestimate of actual marine diversity.

Source:
(https://www.environment.vic.gov.au/biodiversity/victorian-biodiversity-atlas)



Victoria's coastline faces the relatively shallow Bass Strait (av. depth 50m). The continental shelf approaches the mainland at either end of the State. Victoria separated from Tasmania around 8,000 years ago due to rising sea levels.



If you went on a journey through space and arrived at another planet with life forms, it is unlikely that they would be any more extraordinary than what lives here on Earth under the sea. Life most likely began in the sea about four billion years ago and so it's not surprising that we see some remarkable creatures in marine environments.

From the surface we glimpse only a fraction of the vibrant, colourful and intriguing marine life down below. Some insights can be obtained by searching the coast for dislodged and washed-up seaweeds, shells and other marine debris. Underwater it's a world of forests and meadows, caves and sand dunes, a 3D world where humans can 'fly'.

The problems humans must solve to go underwater – relating to water pressure, buoyancy, air supply, movement, visibility and chemical balance – indicate just how different the sea is for terrestrial living organisms.

From the largest living creature (Blue Whale) to microscopic plankton, the sea holds a huge variety of organisms and complex ecosystems. Seagrass beds, rocky reefs, sand, mangroves, beaches and the water column itself provide habitats utilised by marine creatures.

Australia's isolation as an island continent affects the species we find in our waters. The southern coast of Australia is the only major south-facing coastline in the southern hemisphere and has been isolated for 65 million years.[570] Around 90–95% of Victoria's marine species are unique to southern Australia.[571]

Ecosystem outline

VICTORIA'S MARINE environment is anything but uniform.[572] Cold water currents arrive from the west whilst the warm East Australian Current influences the east. In the west the main rock type is made from crushed sea shells (carbonate) whilst in the east it is from quartz rocks (silica). In the shallow, continental waters between Victoria and Tasmania, mud predominates as it does in the large bays. In addition, subaqueous dunes (sandwaves) and tidal current ridges cover some 6,000km^2 of Bass Strait. Powerful waves hit the west coast due to the prevailing westerly winds creating cliffs and rock platforms. These variations are reflected in underwater and intertidal marine ecosystems. The sea's effect extends inland too, for example, influencing the distribution of rainforests on shore.[573]

Living underwater presents many challenges for marine creatures. © Shannon Hurley.

The sea is a three-dimensional space filled with salty water. Water is much denser than air which means that it can support larger body weights but also has the effect of creating high pressure with depth. Invertebrates (those without a backbone) are common and generally bigger than their land-based relatives. The open ocean provides no shelter from predators and so animals must adopt other strategies such as congregating together, sheltering in rock caves or sinking into the darkness of the depths.

The effect of depth

On the land it is altitude, in the sea it is depth below the surface that affects species. Two major factors change with depth – light is filtered and pressure increases. At the surface, green and brown algae occur but at depth or in the shade of other species, red algae do better in the low, filtered light. You can see this in any rock pool. Push away the dominant brown and green seaweeds and beneath them you will see the reds, usually encrusting pink-coloured coralline algae. Deeper again, as light diminishes and then vanishes, plants give way to animals including sponges, bryozoans and gorgonians that can obtain energy 'raining' down from above. There is rarely any significant light beyond 200m depth.

Excess nutrients in Copenhagen harbour have led to this huge, toxic phytoplankton bloom (red).

Forests occur but wood (lignin) is not required as floatation is possible. Many kelps have gas-filled floats attached to their fronds to keep them vertical. Most fish can regulate their depth by pumping gases into internal swim bladders.

The effect of nutrients and catchment

The energy that drives life in the sea comes primarily from the sun but what of the nutrients required for growth? Nutrients travel down rivers as silt or in sea currents. Where they well up from the sea floor, due to strong offshore winds, large populations of marine organisms may occur. The Bonney Upwelling in western Victoria is an example.

Excess nutrients have been linked to loss of seagrass beds in Western Port Bay.[574] Algal blooms are also a potential result of overabundant nutrients.

Temperature, turbidity, salt and oxygen

The chemical composition of seawater (a liquid) is very different to the air (a gas) in which most terrestrial organisms live. On average, seawater contains 3.5% salt and oxygen is much less concentrated (<1%) compared to air (>20%).

Marine fish must pass a lot of seawater through their gills to obtain sufficient oxygen, which then diffuses into their bloodstream.

Salt in seawater poses numerous problems. For example, it passes from seawater into the body of a fish through its gills and skin. Marine fish have specialised kidneys that pump it out.

Sea temperatures are more stable than in terrestrial and freshwater environments. The effect of temperature is profound. It alters the acidity of water, its viscosity, solubility and the chemical reactions within all organisms, including reproduction. For example, one of the potential dangers of warming seas due to climate change is the loss in ability of marine organisms to form shells. Increased ocean acidity causes the form of calcium carbonate used by marine organisms to make shells, aragonite, less available. No shell means no shelter from the environment, including predators, and almost certain death.[575] The thickness (viscosity) of seawater impedes travel and is the reason for the streamlined shape of fast-moving marine organisms such as tuna.

Turbidity can reduce light penetration and silt can smother ground-living organisms. Thus, activities on land that cause siltation of rivers impact marine life, such as seagrass meadows.

Waves and currents

In shallow water, waves and underwater surges, associated with the passage of a wave or current, create strong forces that pull on all organisms and threaten to tear plants from their point of attachment.

Currents, like river flows, present problems to free floating organisms. How can their planktonic young return to their parent's territory? How can poor swimmers, such as jellyfish, avoid being swept to the shore?

Compared to terrestrial environments

Many of the issues for marine animals are the same as on land – finding shelter, surviving competition, avoiding predation, finding a mate and surviving changes in the environment. Fire is not an issue but disease and the occasional tsunami can be catastrophic.

Few organisms are capable of living in both the terrestrial and marine worlds although a number of fish have the capacity to travel to and from fresh to saltwater. Quite amazingly, some terrestrial animals have over long periods of time made their way back into the sea including ancestors of whales, dolphins, seals and penguins.

Some coastal habitats, such as kelp beds, mangroves, saltmarshes and seagrass, produce more plant material annually than the richest agricultural regions on land.

Seaweed types

The plants that occupy the sea and intertidal seashore are collectively called 'seaweeds', the 'weeds' probably reflecting a lack of familiarity with these ecosystems as most of what you see is natural. They are broadly classified by colour into blue-greens, browns, greens and reds.

1. Blue-green (*Rivularia australis*) © Anna Syme CC-BY-NC 4.0 (Int).
2. Brown (*Phyllospora comosa*). © Pete Woodall. CC-BY-NC 4.0 (Int).
3. Green (*Caulerpa scalpelliformis*). © Pamela Melrose. CC-BY-NC 4.0 (Int).
4. Red (Coraline) (*Corallina officinalis*). © Steve Burrows. CC-BY 3.0 (Au).

Algae can reproduce with or without sex. Some simply colonise new areas by breaking off the parent plant. Larger algae tend to produce spores. Some green algae produce spores that can swim using hair-like flagella.

Given these profound differences in environment, we can see that interpreting marine ecosystems is going to be fundamentally different to those on land.

Marine habitats

Intertidal areas

Periwinkles shelter in the rocky intertidal zone. © Stephen Platt.

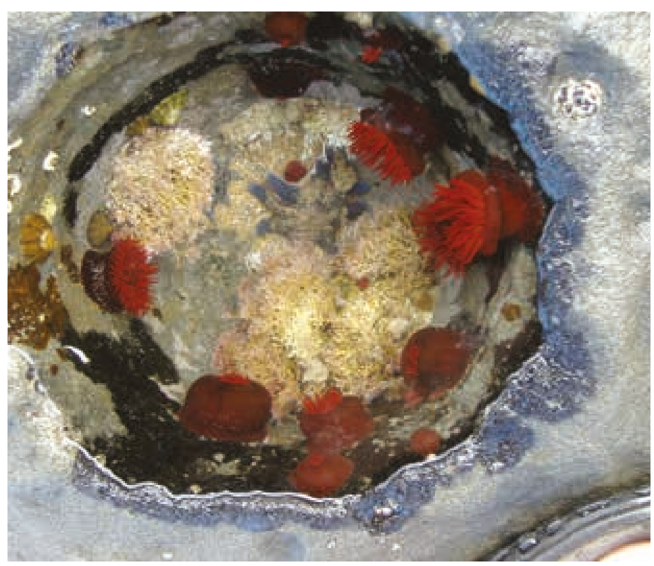
Neptune's Necklace and Sea Lettuce are common algae on intertidal rock platforms. © Stephen Platt.

Each day, due to the pull of the moon, tides of varying amplitude occur along the shoreline. The ability to cope with exposure to the sun, to breathe out of water for periods of time and to survive pounding surf make intertidal areas unique for marine life. On rocky platforms you will find short-in-stature seaweeds such as the brown Neptune's Necklace (*Hormosira banksii)* and green Sea Lettuce (*Ulva lactuca)*.

Clutching to rock faces, shell-covered animals like limpets hold a mini-ocean under their impervious, predator-impeding, surf-resistant shell until the tide returns. Common Limpets (*Cellana tramoserica*) build a flat 'docking station' on a rock to improve suction. Limpet 'teeth' (radula) are made of the strongest natural material known, even stronger than spider's silk! The teeth fibres can withstand a pulling force the equivalent to a strand of spaghetti lifting 1500kg of sugar.[576]

The ability of different organisms to withstand differing periods of exposure may result in a distribution pattern parallel with the shore with the exposure-hardiest species furthest from the sea.

Limpets use their 'teeth' (radula) to scrape algal food off rocks. They can also create a flat surface that assists suction onto their home rock when predators approach.
Above: © Stephen Platt. Below: Royal Society CC BY 4.0.



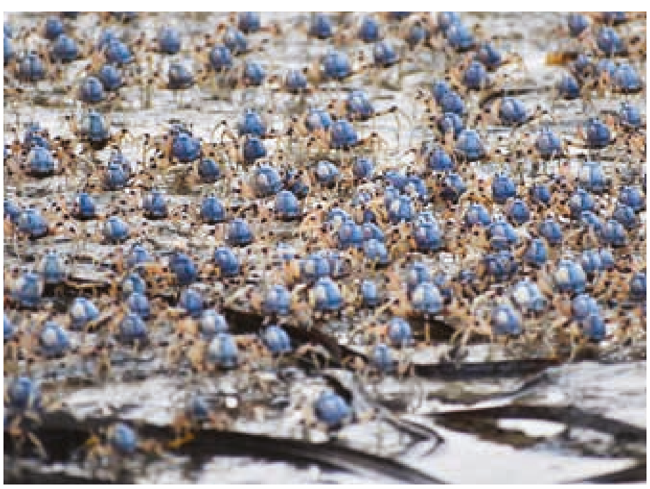
Intertidal rockpools offer refuge to sea anemones (with stinging tentacles), starfish, limpets, blue-green algae (dark), tube worms (white) and coralline algae (pink). © Stephen Platt.

Southern Blue-ringed Octopus. Christopher Mark. CC-BY-NC 4.0 (Int)

Sometimes found on intertidal rock platforms, the reef-dwelling Southern Blue-ringed Octopus (*Hapalochlaena maculosa*), despite its small size (10cm) and iridescent beauty, is a very dangerous animal that should not be handled. If envenomated by its poison, respiratory failure in humans can occur within minutes and can be fatal. However, if resuscitation is maintained, patients can recover. Chillingly, the affected person, though unable to communicate, remains aware and can hear. They need reassurance throughout their recovery.

The female octopus lays her eggs one month after copulating for an hour with her mate. Instead of attaching them to the substrate, she cradles them between her raised skirt and body, moving them about as necessary. During this time, she does not feed. The young reverse orientation inside the egg just prior to hatching and emerge mantle-first. The adult female dies shortly afterward. The young settle to the bottom and consume their remaining yolk sac. Within a week they will be feeding off pieces of crab and within a month hunting live crabs which they pierce where the shell meets the tail, inject their prey with venom and sucking out the partially-digested contents. At six weeks the iridescent blue rings will appear. Maturity is attained at four months[577] and total lifespan is up to two years.

Beaches



Soldier Crabs. © Elise CC-BY-NC 4.0 (Int).

If you walk along a flat beach toward an army of Soldier Crabs (*Mictyris longicarpus*) by the time you arrive it is easy to wonder if you have been misled by a mirage – they have disappeared. Soldier crabs spend most of their time beneath the sand, spiralling down from the beach surface rapidly to around 20cm depth when threatened and between low tides. The number and sex of the crabs that emerge on a particular day depends on the temperature, wind and rainfall.[578] Following emergence, they perform a 'half somersault' to remove any sand.

The tide carries with it a scum of floating detritus and small organisms that gets deposited on the beach as a fine film. Soldier Crabs are superbly designed to scrape up this layer, extract the organic material and leave behind a small ball of processed sand. Unlike most crabs, they are able to walk forwards. After feeding, crabs may congregate into 'armies', generally composed of males with larger individuals at the front.

As the tide returns, soldier crabs corkscrew down into the sand where they are relatively safe. Their predators include Straw-necked Ibis, Great Egret, Common Toadfish and other crabs.

Pied Oystercatchers. © J J Harrison. CC SA 3.0 Unported.

Birds are an integral part of the marine ecosystem. Along the entire coastline, including mudflats, pairs of Pied Oystercatchers (*Haematopus longirostris*) are common. They find prey, of sandworms, crabs and cockles (bivalve molluscs), by sight and by probing with their robust beak, making particular use of the receding tide when these organisms are closer to the surface.

Camouflaged eggs of monogamous pairs are laid on the sand at the top of the beach. You can tell when a nest is close because the adults will become agitated. At that time its best to retrace your footsteps or move down to the water's edge to avoid stepping on the nest.

Appearing like jellyfish, these crescent-shaped masses are produced by a Moon Snail (*Polinices* sp.) and contain its eggs. Powlett River, near Kilcunda. © Stephen Platt.

In dim light, with less competition from seaweeds, sponge gardens occur. © Daniel Ierodiaconou.

Moon Snail (*Polinices conicus*).
© Mark Norman, Museums Victoria. Public Domain.[579]

Bull Kelp *Durvillaea potatorum* has a disc-shaped holdfast that secures it to its rocky substrate. © John Turnbull. CC-BY-NC-SA 4.0 (Int).

Rocky reefs

Rock is a much more stable substrate than sand or mud. It forms shelves, caves and cracks. Here we find rocky reef marine communities. The depth of the rock, exposure to currents and wave action will affect the species present.

The presence of light-needy, green algae (*Caulerpa flexilis*) on this reef indicate that it is at relatively shallow depth.
© Julian Finn, Museums Victoria. CC-BY.

Rocky reefs provide a secure foothold for seaweeds that may be buffeted by waves or strong currents. Reefs also provide a myriad of cracks, crevices and pools for animal species to hide in and so escape predators.

The Southern Rock Lobster 'crayfish' (*Jasus edwardsii*) is a large, carnivorous crustacean that is better known on a dinner plate than for its ecology. It lives on coastal reefs to depths of 200 metres and is not closely related to freshwater 'lobsters' or yabbies. The female carries up to half a million eggs in her tail for three months until they hatch in spring (Oct–Nov). The microscopic larvae undergo 13 developmental stages as they travel about on ocean currents. Then they settle on an inshore reef. They must shed their hard, outer covering (carapace) to grow and this happens frequently when young and once-annually when an adult. A ten-year-old male crayfish is around 16cm long (female 12cm). They feed at night on bottom-dwelling invertebrates including molluscs, crustaceans and starfish (echinoderms). Their predators include octopus and large fish including sharks.[580]

Lobsters play important roles in marine ecosystems. For example, they eat sea urchins including those covered in spines. This helps to regulate urchin numbers.

Overabundant sea urchins can lead to problems including the loss of kelp beds. Urchins eat kelp. Too many sea urchins can lead to loss of kelp forests and their associated species. The resulting bare area is called an 'urchin barren'. Urchins thrive when crayfish are reduced in number or absent, when water temperature improves survival of urchins and when increased nutrients favours algal growth that supports juvenile urchins. An overabundance of urchins (>8/m^2), has occurred in Port Phillip Bay.[581,582,583] The change to an 'urchin barren' can be permanent as, once the kelp has gone, urchins can switch to other foods.

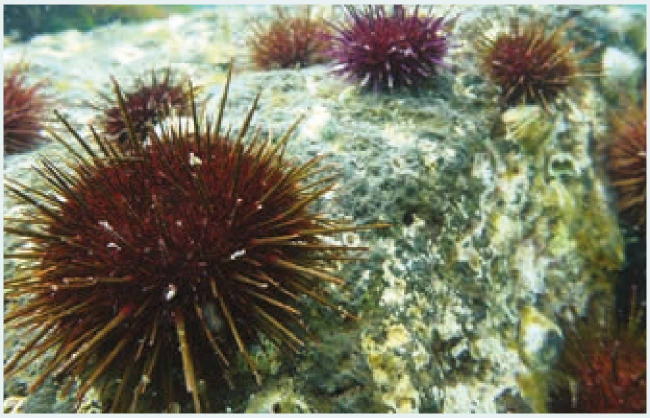
But urchins have another role. They protect juvenile abalone, which graze on rock-encrusting coralline algae. An overabundance of crayfish can lead to fewer urchins and thus to a decline in abalone.[584] In contrast, loss of kelp disadvantages adult abalone.

Kelp provides structural habitat for many sea animals and, when detached by storms, washes ashore as beach wracks. These wracks are home to many invertebrates (e.g., sea lice) and, as they rot, release nutrients that ultimately support the food web of crayfish.

Natural regulation of species' abundances in these complex systems is achieved by the interactions between numerous species and their environment. Understanding these relationships – the *system* – is essential if we wish to continue to benefit from eating seafood.

Port Jackson Sharks (*Heterodontus portusjacksoni*) are active at night. During the day they can be found resting on the sea floor in reef caves and other areas protected from currents. Adults are social and associate with other sharks. They have the unusual ability, for a shark, to eat and pump water over their gills at the same time and without swimming. Their diet includes sea urchins, starfish, polychaete worms, large gastropods (sea slugs, sea hares, nudibranchs etc.), prawns, crabs, barnacles and small fish. To discard any unwanted contents they consume, they are able to turn their stomach inside out and eject them out of their mouth. They attain maturity at 11–14 years of age.

Southern Rock Lobster. David Muirhead CC-BY-NC 4.0 (Int.).



Overabundant sea urchins in Port Phillip Bay. © Scott Ling.

Greenlip Abalone (*Haliotis laevigata*).
© David Muirhead. CC-BY-NC 4.0 (Int).

Port Jackson Shark. © Erik Schlogl. CC-BY-NC 4.0 (Int).

Female Port Jackson Shark carrying its egg ready for placement into a reef crevice. © Australian Museum.

During the breeding season from August to mid-November, some male sharks, followed by females, move to inshore reefs.[585] Unpaired males remain in deeper water. Breeding pairs congregate in caves, returning to the same breeding sites each year. The female produces eggs in pairs every 10–14 days to a total of 10 to 16 eggs. The eggs look remarkably like brown seaweed. She uses her mouth to wedge the soft egg into a rock crevice where it hardens. Some 10 – 12 months later a young shark will hatch. Many empty and full egg cases wash up along Victorian beaches.

These sharks are capable of learning from their environment. Juveniles have unique personality traits, some individuals being much bolder than others.

The Port Jackson Shark's role in eating starfish and sea urchins (echinoderms) and thus regulating their numbers, probably helps to maintain populations of molluscs and seaweeds (algae).

It looks like another odd piece of seaweed but is actually a Port Jackson Shark egg. This one wasn't securely wedged into a reef and has been washed ashore. The yellow yolk can be seen through the cut. © Stephen Platt.

Nudibranchs are carnivorous, reef-dwelling sea snails that lose their shells at the larval stage of development. The name nudibranch means 'naked gills', which are evident as branching structures on the back.

Having abandoned the shell, different nudibranch species have evolved a range of tactics to avoid predators. Some are camouflaged, some move at night, some are poisonous or foul tasting, some mimic poisonous species (aposematism), others incorporate stinging cells from their hydroid prey into their body and yet others secrete acid from their skin.

The primary sense used for navigation is chemical. They track the smell of their seaweed food rather than see it.

Nudibranchs have both male and female sex organs (are hermaphrodites) but do not inseminate themselves. Mating involves a courtship 'dance'. The resulting egg 'ribbons' can contain poison obtained from the sponges they eat.

Nudibranchs live for anything from a few weeks to a year depending on the species.

Some nudibranch species produce noises audible to humans. Some contain single-celled algae (zoozanthellae) which live in their body and supply sugars to their host.

***Phyllodesmium macphersonae* feeds on octocoral. Its body contains a single-celled, golden-brown algae (zooxanthellae, a kind of dinoflagellate).** © John Eichler. CC-BY-NC 4.0 (Int).

Vercoe's Nudibranch (*Tambja verconis*) feeds on bryozoans. Its 'naked gills' are the branching, blue structures on its back.
Julian Finn / Museums Victoria, CC BY.

The Short-tailed Sea Slug (*Ceratosoma brevicaudatum*), eats sponges. Victoria's biggest and most common nudibranch.
© Julian Finn / Museums Victoria, CC BY.

Walking Seahare (*Aplysia juliana*) in a rock pool at Kilcunda.
© Stephen Platt.

Compton's Cowrie (*Notocypraea comptonii)* is common in Victorian waters. © Ron Greer. CC-BY-NC 4.0 (Int).

Across human history, cowries have been traded as money, used in rituals and made into jewellery. The cowrie is a kind of sea snail (mollusc). Their shells are often found washed up on beaches adjacent to the rocky reefs they live on. The living shells, unlike those washed ashore, are very smooth because they are usually covered by a fleshy mantle. Cowries are nocturnally active and known to eat sponges. During daylight they shelter under rocks and rubble.

Mating involves the male climbing onto the female and inserting his penis into her mantle cavity. Egg capsules are laid and brooding females remain with them.

Giant Cuttlefish. © Glen G. Gitsham. CC BY-NC 4.0. (Int).

Cuttlebone. © Nick Lambert. CC BY-NC-SA 4.0.

Walk any beach in Victoria and you will find 'cuttlebones' washed ashore. The stranded cuttlebone once belonged to a living cuttlefish, which is in the same family as octopus and squid. The cuttlebone is made of aragonite (a form of calcium carbonate) and is used for buoyancy control. This is done by changing the gas to liquid content of the spaces in the cuttle. Break a cuttlebone in half and you will see the spaces, between upright pillars, used to hold the gas. Cuttlebones have another use. Note the sharp point at one end of the cuttle. It is there to deter predators.

Giant Cuttlefish (*Sepia apama*) attract mates with a dazzling display of colour made possible by brain control of their skin cells. By rapidly changing the colour and pattern of their skin, they can mimic rock, sand or seaweed. After mating, the female lays her eggs on the underside of a rocky cavern. Then the adults both die. The developing embryos can see before they hatch in three to five months. Cuttlefish spend most (95%) of the day resting and hunt for crustaceans and fish over short periods (3.7% of the day). They cannot see colour but can detect the polarisation of light. Cuttlefish are eaten by a wide range of species including Indo-Pacific Bottlenose Dolphins and New Zealand Fur Seals.

Sandscapes

Sand is an unstable substrate and tends to only support plants in sheltered locations. Being pervious, many species, such as rays and flounder, bury themselves under sand to hide from predators or ambush prey.

Every year in winter, thousands of Giant Spider Crabs (*Leptomithrax gaimardii*) congregate in Port Phillip Bay. At first glance this seems like a strange strategy that exposes the normally solitary crabs to predation, as seals, birds, octopus and rays feast on them. However, the crabs face a dilemma. In order to grow they must shed their protective outer shell. By getting together, each crab faces a lower individual risk of being eaten during the hour-long period it takes for its replacement inner shell to harden. The reduction in individual risk by being part of a group explains, at least in part, why fish school, birds flock and many large mammals form herds. Where the crabs go to after moulting is currently unknown.

Southern Eagle Rays (*Myliobatis australis*) are common inhabitants of shallow near shore, sand flats and reefs. They feed on small fish and invertebrates including crabs, shellfish and worms. For defence, they have a venomous spine on their tail. Females give birth to live young.

Mass congregations of Giant Spider Crabs occur annually during winter in Port Phillip Bay. Predators, such as Smooth Stingrays, prey on the crabs while they shed their old shell in order to grow. © Julian Finn, Museums Victoria.

Southern Eagle Ray. © Lucy Smiechura. CC-BY-NC 4.0 (Int).

Giant Spider Crabs. © Julian Finn, Museums Victoria. CC BY.

Seagrass meadows

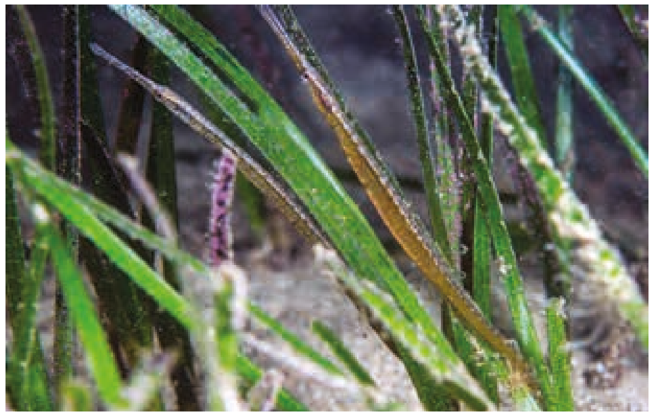
Australia-wide, thirty species of flowering plant have managed to colonise the sea.[586] These 'seagrasses' usually occur in sheltered, shallow, sandy and muddy bays and inlets up to eight metres deep. While most seagrasses require sheltered waters, in order not to be uprooted by wave action and currents, Sea Nymph (*Amphibolis antarctica)* is common on exposed rocky coasts.

Seagrasses need abundant light in order to grow. They obtain nutrients through extensive root systems. Seagrasses reproduce using pollen which is transferred between their tiny flowers by water currents. They play an important role in stabilizing the seafloor and as nursery areas for juvenile marine organisms.

On the leaves of seagrasses, you will notice small pink crusts of a red coralline algae. Hidden among the upright stems are pipefish, which mimic the seagrass by shape, body orientation and movement. They are related to seahorses and seadragons.

Common Seadragons (*Phyllopteryx taeniolatus*) are fish that drift around in unison with the seaweeds they inhabit, relying on their camouflage for protection. Female dragons lay up to 120 eggs on the underside of the male's tail where they are fertilised. He will care for the eggs for up to a month before they hatch. Common Seadragons eat zooplankton which they suck into their tube-like toothless mouth. They may live for up to six years.

Seagrass meadow, Rickett's Point. © Shannon Hurley.



Two Wide-bodied Pipefish (*Stigmatopora nigra*) are well concealed in their seagrass (*Zostera* sp.) habitat.
© Stephen Coutts. CC-BY-NC 4.0 (Int)

Common Seadragon. © Katieleeosborne. CC SA 4.0 (Int.).

Rhodolith beds

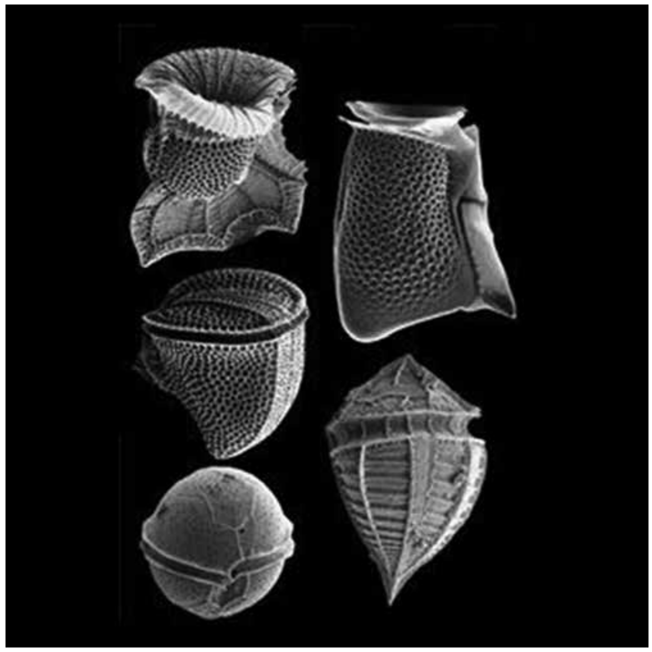
Rhodolith bed off San Remo. © Sean Blake.

Rhodolith beds are marine habitats that consist of unattached nodules of calcium created by red-coloured, coralline algae of several species that may grow singularly or together. They occur along 70% of Australia's coastline to a depth of 170m [587,588] often in the transition between rocky reefs and open sandscapes.

Open ocean and water column

Plankton is a term used to describe all the organisms, from microscopic to jellyfish-size, that are poor swimmers and flow with the ocean currents. There is an astonishing variety of forms. They are the basis of most marine food chains feeding everything from small mussels to whales. Rising at night and descending by day allows many of these organisms to minimise predation. Some are bioluminescent, emitting light.

Phytoplankton release oxygen into the water as a biproduct of their photosynthesis. It is estimated that half of the world's oxygen, essential for human life, is produced in this manner. Another key ecological role that zooplankton performs is as the primary food of almost all larval fish.



Some of the great variety of Victorian dinoflagellates. Microscopic and invisible to the naked eye, you are immersed in these amazing creatures whenever you swim in the sea.

© David Hill, University of Melbourne.

The Blue-bottle looks like a jellyfish, but isn't.

© Julian Finn. CC BY 4.0 (Int).

Blue Bottles (*Physalia utriculus*), are hydrozoans, not jellyfish. They are a colonial organism made up of genetically distinct parts, called zooids, that co-operate as though they were a single organism. The tentacles are capable of inflicting a sting sufficient to stun small fish. The inflated bladder atop the tentacles is both a floatation device and sail for travel by wind across the ocean surface. Loggerhead Turtles (*Caretta caretta*), Blue Sea Slugs, Blanket Octopus (*Tremoctopus violaceus*) and Sunfish species prey on Blue Bottles.

The Blue Sea Slug (*Glaucus atlanticus*) is a poisonous nudibranch that feeds on Blue Bottles. The stinging cells of its prey are incorporated into its body for self-defence. It lives floating upside-down with the help of a bubble which it swallows and keeps in its stomach. This species is counter-shaded – ocean blue when viewed from above and sea/sky grey from below. Victorian records of this species are only from the far east. © Unknown. CC-BY-SA 4.0 (Int).

A female Knobbed Argonaut (*Argonauta nodosus*) Argonauts produce the 'paper nautilus' that washes up on Victoria's beaches. It's not a shell, so what is it? © David Paul. dpimages.

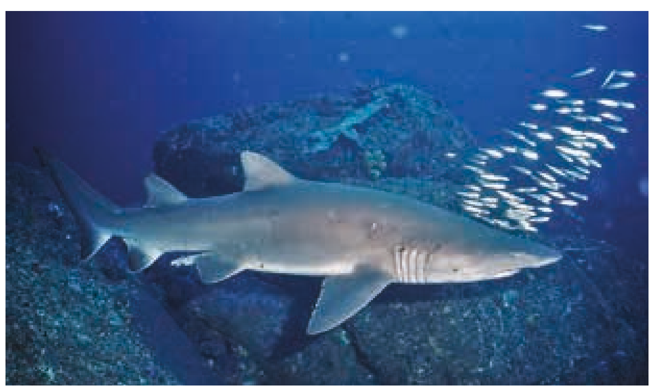
Every so often you will find 'paper nautilus shells' washed up on Victoria's beaches. They are not shells but in fact the paper-thin egg case produced by the female of a marine invertebrate, an octopus of the open ocean (pelagic) called an argonaut. No one knows why masses of their 'shells' wash up at certain times and not others. Argonauts live close to the surface. Females grow up to 10cm and make egg cases up to 30cm in size whilst males are much smaller at 2cm. The egg case is also used for buoyancy.

Reproduction involves the male inserting a specialised arm loaded with sperm into a cavity of the female. He then probably dies. Creepily, the detached arm crawls into her gill cavity and is held until she is ready to use it. Indicative of her possible promiscuity, females have been found with multiple arms attached to their gills. She protects the eggs until they hatch. Argonauts feed on crustaceans, molluscs, jellyfish and salps (sea squirts) injecting them with poison. They use their 'beak' to drill through the shell of molluscs. Argonauts are preyed on by larger species including tuna and dolphins. Their defence includes an ability to change colour rapidly to blend in with their surroundings and production of ink, which they eject with force as a visual shield and chemical deterrent as they rapidly swim away.[589,590,591]

Grey Nurse Sharks (*Carcharias taurus*) are large, nocturnal, marine predators. They are slow-moving, bottom dwellers. A female produces eggs that hatch inside her (ovoviviparous). There is no placental-like connection. Instead, the most developed embryos obtain nourishment by eating the remaining embryos and unfertilised eggs whilst still inside their mother (known as intra-uterine cannibalism). Grey Nurse Sharks eat mainly lobsters, crabs, smaller sharks, fish, rays and squid. They co-operate to round up motile prey. Their lifespan is 30–40 years.[592]

This species was once widespread in Victoria including in Port Phillip Bay. In the past, fears about Grey Nurse Sharks[593] led to them being indiscriminately killed, including during the latter half of the nineteenth century in Victoria when a bounty was placed on them. Now we know that they feed almost exclusively on fish so the risk to humans is very low. Grey Nurse Sharks are virtually extinct in Victoria and the east coast population is severely depleted. A national recovery plan is in place.

School Sharks (*Galeorhinus galeus*), one of the species sold in fish and chip shops as 'flake', travel between Victoria and New Zealand, with individual migrations of over 3,000km. They live for over 50 years and females start breeding at 10 years. Gestation is six months and an average of 26 young are born but this happens once in two to three years.



Grey Nurse Shark. © John Sear. CC-BY-NC 4.0 (Int).

Co-operative feeding by Grey Nurse Sharks.
© Tony Strazzari. CC-BY-NC 4.0 (Int).

Shy Albatross. © leitchbird. CC-BY-NC 4.0 (Int).

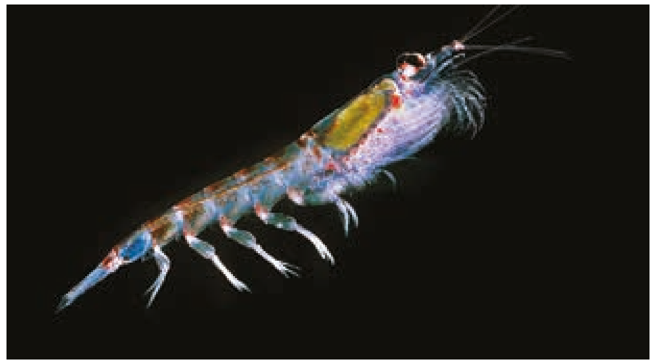
If you are looking out to sea from Victoria's coast using binoculars and see an albatross, it is most likely to be a Shy Albatross (*Thalassarche cauta*). Occasionally seen in groups of hundreds, they are in reality far from shy. This remarkable bird is capable of flying 1000km in 24 hours. It breeds on offshore islands in Bass Strait and off Tasmania. One egg is laid in spring. The Shy Albatross both dives and surface-feeds for fish, cephalopods (octopus, squid), crustaceans and tunicates. Shy Albatross' live for up to 60 years.

Bioluminescence and bioflourescence

Many marine and terrestrial organisms are capable of 'glowing in the dark' or ejecting glowing fluids. Light is used to attract prey, escape prey and to attract a mate. In bioluminescence, light is produced by a chemical reaction of luciferin with oxygen. Sunlight is not involved.

Bioflourescence involves absorbing sunlight and then re-emitting it. Platypus, wombats and scorpions glow under fluorescent light. It is unknown why but may relate to their activity at dusk and overnight.

One way of experiencing the wonder of marine plankton bioluminescence is, by the shore at night, to scuffle your feet in the shallows which, if the appropriate species are present, may trigger a light display.



Antarctic Krill (*Euphausia superba*) produce bioluminescence in the 'red organs'. © Uwe Kils. CC SA 3.0 Unported.

Chapter cover: Sponges dominate this site, not seaweeds which require light. Light declines with depth and under overhangs and in caves. The predominance of sponges and absence of light-needy algae, suggests that this photograph is taken at considerable depth. © Daniel Ierodiaconou.

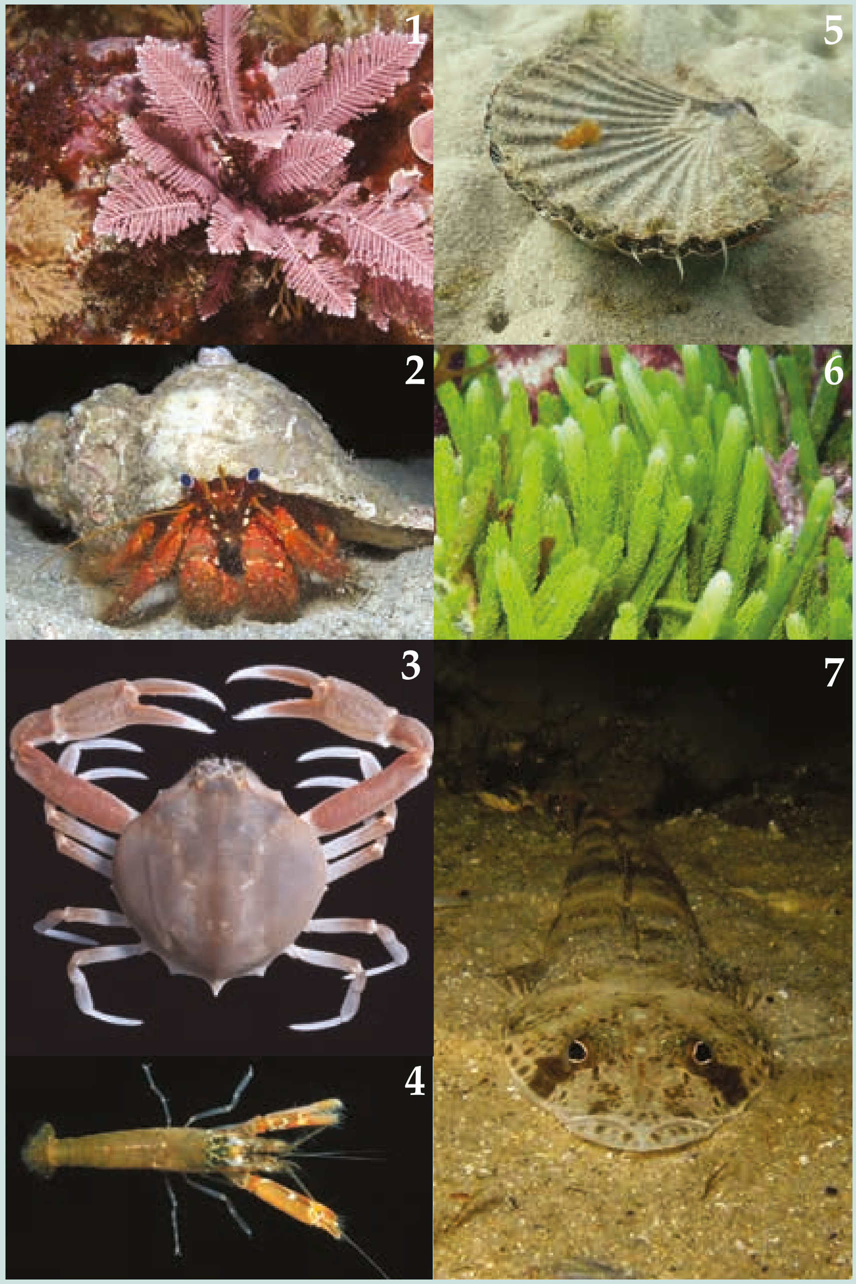
There have been over 271 species of sponges collected from Port Phillip Heads, where the Bay opens up to Bass Strait. This represents a substantial proportion of the 523 known species from Victoria and the 1,416 known species from across Australia. Currently, 115 sponge species are presently considered unique to the area.

https://www.ces.vic.gov.au/sotb/case-study/there%E2%80%99s-garden-down-there-spectacular-gardens-hidden-under-heads

Where to see this ecosystem

- Any of Victoria's system of Marine National Parks and Marine Sanctuaries:
  - Discovery Bay Marine National Park.
  - Twelve Apostles Marine National Park.
  - Point Addis Marine National Park.
  - Port Phillip Heads Marine National Park.
  - Yaringa Marine National Park.
  - French Island Marine National Park.
  - Churchill Island Marine National Park.
  - Bunurong Marine National Park.
- Whales, seals, penguins and other seabirds can be seen from any beach or clifftop lookout (e.g., Airey's Inlet, Warrnambool, Phillip Island, Cape Bridgewater, Cape Otway).
- Rock platforms and pools along the Victorian coast (e.g., Cape Otway, Cape Liptrap, Cape Schank)
- Waders – are most easily seen when they congregate at high tide. The shores of Westernport Bay and the Western Treatment Plant are well-known locations.
- Scuba diving anywhere along the coast (e.g., Port Phillip Bay, Wilson's Promontory, Port Campbell, Cape Schank).

Some of the amazing creatures in Port Phillip Bay.



1. Coralline algae (*Corallina officinalis*). © Julian Finn, Museums Victoria. CC BY.

2. Hermit Crab (*Strigopagurus strigimanus*). © Julian Finn, Museums Victoria. CC BY.

3. *Bellidilia undecimspinosa*. © Michael Marmach. CC-BY-NC.

4. *Alpheus parasocialis*. © Michael Marmach. CC BY NC

5. Commercial Scallop (*Pecten fumatus*). John Sear. CC-BY-NC 4.0 (Int).

6. Green Seaweed (*Caulerpa brownii*). © Julian Finn. Museums Victoria. CC BY.

7. Southern Sand Flathead (*Platycephalus bassensis*). © Sarah Speight. CC BY-NC-SA

https://portphillipmarinelife.net.au/species/6318

A new relationship with nature

Reflections. What should our relationship with nature be? What is your relationship?

© Stephen Platt.

A new relationship with nature

Where we've come from

IT STILL feels like we are at war with nature and there is no doubt that, in the short term, nature is losing. WWF-Australia predicts that three to six million hectares of wildlife habitat will be cleared in eastern Australia between 2010–30. Australia's pesticide market, aimed primarily at invertebrates, is valued at $1.6 billion. If you accept that we are part of nature, it is a war that *we* can only lose.

Some of the historical perspectives on nature are briefly outlined below. Have we learnt to 'live with nature'?

Aboriginal practices and respect for country

The Victorian landscape, as it was prior to European settlement, was actively being managed by Aboriginal people. There were forms of housing, aquaculture, agriculture and manipulation of some types of vegetation using fire. 'Country' was more than an asset to be utilised or traded, it related to people's identity. People were part of nature, not separate to it. That is not to say that plants and animals were not utilised, they were but at a level and in ways that allowed most to persist. The land was intimately linked to stories of creation, animal totems were assigned to individuals, and those animals were revered. Life rituals were performed in the landscape. Food came from nature, not from farms. Knowledge of the natural world and how it operates was a life and death matter for every mob. It was a completely different approach to what was soon to rapidly replace it.

European practices in managing land

Settlement of Victoria from the 1830s was swift, agriculture thrived, and the human population was spurred on by the 1850s gold rush. Squatting led to freehold titles that gave exclusive use to areas of land. Early on, unregulated hunting meant that wildlife was anyone's to be taken and many species were slaughtered for food, fur, feathers, or because they were a nuisance to other activities. Use of dangerous poisons, such as strychnine, to kill unwanted wildlife was rampant.

Many aspects of this early approach continue today. For example, despite science showing that the main dietary item of the Wedge-tailed Eagle is introduced rabbit, a pest, in 2018 a farm worker was found guilty of poisoning 480 of these magnificent birds in Gippsland.

Wedge-tailed Eagle (*Aquila audax*). © Kimbo44. CC-BY-NC 4.0 (Int).

Clearing

"….There is apparently every reason to fear that in a few years' time the natural beauties of Australia, that owe their attractiveness to its woods and forests, will have disappeared. The unique outgrowths of the Australian soil being swept away from sight, year after year as the iron of cultivation is wielded…..so surely will the day come when large sums of money will have to be spent in replanting the trees which are now so eagerly destroyed." Snowy River Mail, Sept. 13, 1890.

Clearing wildlife habitats for human use has completely altered many ecosystems. Over two thirds of Victoria has lost almost all of its native vegetation. Source: DELWP. Public domain.

Mountain Ash being felled using springboards c. 1884–1917.[594]
Source: Powerhouse Museum, Sydney.

Carting 'mallee roots' to the woodyard in 1933.
Source: Museums Victoria http://collections. museumsvictoria.com.au/items/770269.

Poisoning

In the early years of settlement, strychnine, arsenic, cyanide and many other poisons were widely used. For example, *"…I fed three ounces of strychnine and 150 lb of oats to a flock of Sulphur-crested Cockatoos…animals that died in plenty were rat-kangaroos, possums, native-cats, tiger-cats, bandicoots of several species, goannas like dwarf prehistoric monsters, wombats, wallabies and kangaroos…all grain eaters and flesh eaters were vulnerable."*.[595]

Similar practices continue today: *"…it is instructive to examine the effects of poisoning mice with strychnine-treated grain during the 1994 mouse plague, when three of six sites in the Wimmera and two of four sites in the Mallee were poisoned: Strychnine was not effective in reducing the number of mice and did not reduce the level of damage to crops in the Mallee, but did reduce damage in the Wimmera…"*[596]

Hunting and fishing

Hunting wildlife for food, 'sport' or merchandise was so prolific immediately after settlement that in 1862 Horace William Wheelwright lamented the rapidly declining resource.

In January 1905, The Argus reported *"In 1903–04 just one London dealer handled almost four million possum skins, 820,000 wallaby skins, 355,000 wombat pelts and 27,000 kangaroo skins – more than 5 million animals".*

Victoria's Game Management Authority reports that around 52,501 people are licensed to hunt game in Victoria in 2020.[597] Ninety-seven percent are male.

Killing wildlife for 'sport' and as a supplementary food source continues to this day as a cultural tradition. Source: Mitchell Library.

Historic duck hunter's camp with over 30 ducks hung from a line. Source: DELWP. Public domain.

Bushmen photographed with their dogs in front of a wall of animal skins (including koala pelts), between 1870 and 1900. Source: Mitchell Library, State Library of New South Wales, Australia, SPF/1457. Reference code: 910625

Introducing exotic species

Perhaps the greatest foolishness of all, and one with profound consequences, was the deliberate introduction of animals and plants to Victoria. This was driven by the Victorian Acclimatisation Society, established in 1861, and supported by the then heads of both the Museum and Botanic Gardens.

The following extracts are from Eric Rolls' 1969 book 'They all Ran Wild: the animals and plants that plague Australia'.[598]

Species introduced included rabbits, starlings, sparrows, carp, sambar deer, and grey squirrels.[599] *Mongoose were let loose to try and control rabbits* (p.299). The Society had other species in mind including monkeys *"for the amusement of the wayfarer whom their gambols would delight as he lay under some gum-tree in the forest on a sultry day"* and boa constrictors believing *"…that they are exceedingly useful in devouring other snakes of a highly venomous nature"*![600]

"I differ from my predecessor—I do not like monkeys but I have no objection whatever to boa-constrictors… The boa of the Cape is not of that enormous, I believe, fabulous size, sometimes spoken of, resembling a log of wood upon which a person might innocently sit down upon, nor has it a throat of such dimensions as to swallow men, as old stories would lead us to believe. Indeed, it is in reality not much thicker than my wrist… The boa-constrictor can, in fact, be made one of the most interesting drawing-room pets possible; and I have often had them twining round about my own body, while Miss Darling has made playmates of them when a child. I have also seen them introduced suddenly amongst a party and made to rear their heads over a piano; ". (p278).

And of the birds that were introduced:

"There could be no doubt, he said, that those delightful reminders of our English home would even now have spread from that centre over a great part of the colony, and the plains, the bush and the forest would have had their present savage silence, or worse, enlivened by those varied touching, joyous strains of Heaven-taught melody which, our earliest records show, have always done good to man… all have been able ere this to have enjoyed one result of the Society's labours in hearing so many of those songsters wild about us." (p295–6).

Ignorance of the Australian bush led to gross misconceptions like there being a 'savage silence' due to lack of melodic songbirds. The situation is quite the opposite as Tim Low's 2017 book 'Where song began" clearly demonstrates. We are blessed with being the centre of songbird diversification.

Today, there are around 1,484 taxa of introduced plants and 81 taxa of non-marine, introduced vertebrate animals, in Victoria.

Legislating

Concern about over-hunting, particularly the sustainability of future hunting, led to the first legislation protecting 'wildlife', 'An *Act to Provide for the Protection of Imported Game* and During the Breeding Season of Native Game'.[601] Enacted in 1862, it was the earliest legislation to protect wildlife in Victoria.

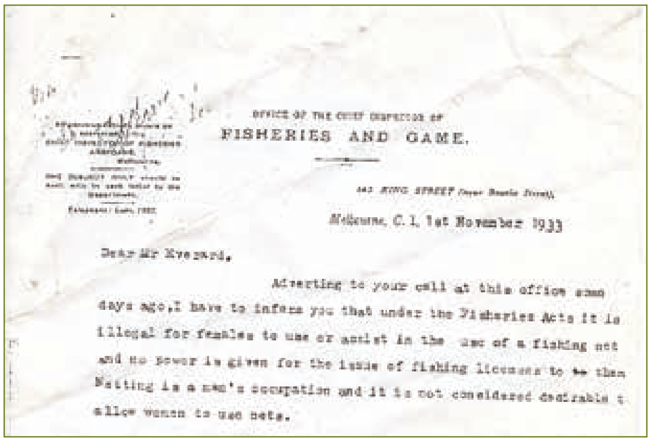
In 1975, the *Wildlife Act* declared all native species protected unless they were declared unprotected. We had at least reached a point of understanding that all creatures mattered, if not the plants.

In 1988, the *Flora and Fauna Guarantee Act* sought to conserve threatened species and ecological communities. Plants, animals, the communities they form and the processes that threaten them could be nominated by anyone for assessment by a scientific committee and listed giving them a legal status. National legislation followed in 1999 as the *Environment Protection and Biodiversity Conservation Act* (EPBC Act).

In 2009, the Victorian Auditor General's review of the *Flora and Fauna Guarantee Act* concluded "it is not possible to conclude whether the Act has achieved its primary objectives. The available data, which is patchy, indicates that it has not." Similar conclusions were drawn in a review of the EPBC Act.

Cultural attitudes

Cultural attitudes change with time. Whilst we really have no choice but to live with nature because of the services it provides (e.g., clean water, pollination, decomposition), we need to behave accordingly. 'Living with nature', 'being part of nature' needs to be part of our psyche.



OFFICE OF THE CHIEF INSPECTOR OF

FISHERIES AND GAME.

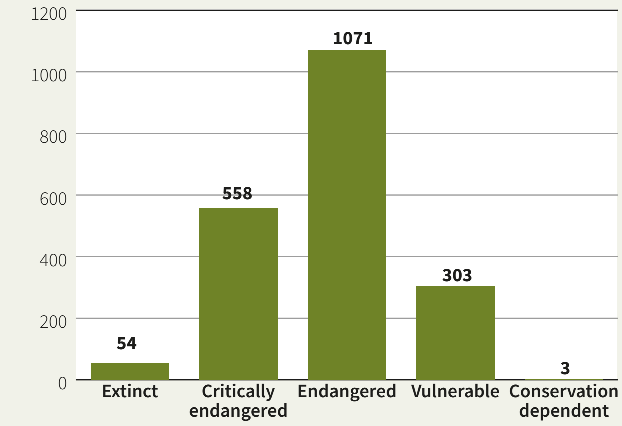
Melbourne, C.1, 1st November 1933

Dear Mr Everard,

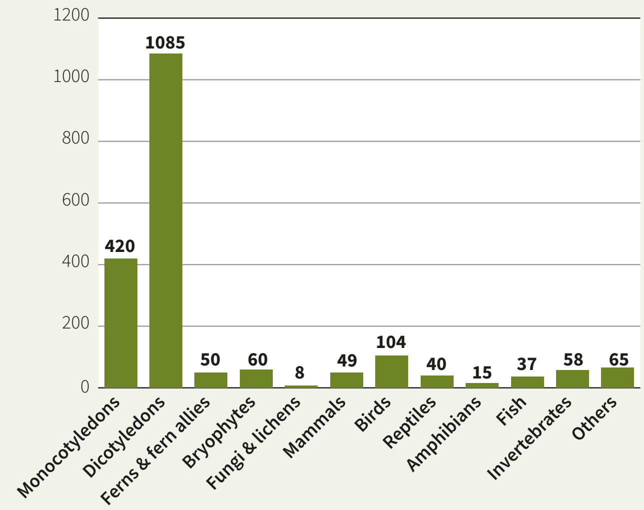
Adverting to your call at this office some days ago, I have to inform you that under the Fisheries Acts it is illegal for females to use or assist in the use of a fishing net and no power is given for the issue of fishing licenses to them. Netting is a man's occupation and it is not considered desirable to allow women to use nets.

An example of how cultural attitudes have changed.

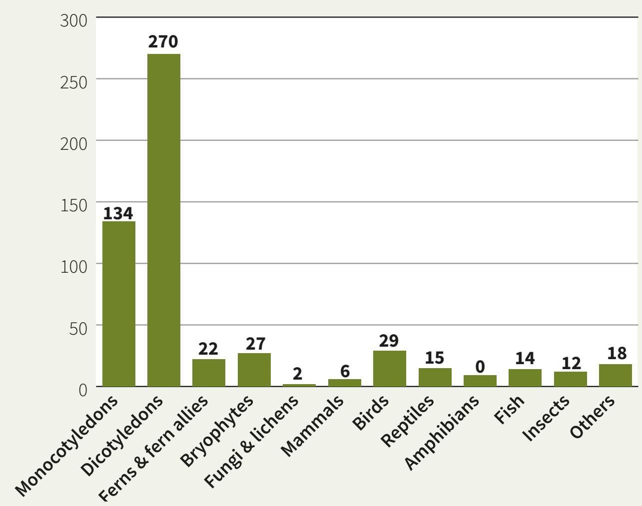
The consequences



Number of extinct and threatened species in Victoria by category of threat. Data source: DELWP.



Number of threatened taxa in Victoria by taxon type.
Data source: DELWP.



Number of 'critically endangered' taxa in Victoria by taxon type. These taxa are closest to the extinction 'cliff'. Put another way, there are 29 bird species our children may never have the opportunity to experience; birds such as the Regent Honeyeater, the Glossy Black-cockatoo and so on.
Data source: DELWP.

One example in too many

The fate of the 'native cat' or Eastern Quoll in Victoria is but one example of the pathway to extinction. The story goes like this. Back in 1861, Horace William Wheelwright encapsulated the experience of most early settlers in south-eastern Australia when he described the 'little Native Cat' as *"One of the commonest of all bush animals".* By all accounts, the native cat was abundant around Melbourne and in many other parts of Victoria. This beautiful animal is a carnivore that primarily targets invertebrates.[602] Much as foxes do today, it sought food from the new farms being established by the colony. For this, it was persecuted by settlers due to its alleged 'depredations on poultry'.

Eastern Quoll (*Dasyurus viverrinus*). © Brett Vercoe, CC-BY-NC 4.0 (Int).

John Halifax, writing of the Lilydale district in about 1880 stated *"I have seen them running away from the carcase in scores on moonlit nights".* J.S. Adams of the Cape Schanck district noted in the 1880s that *"Fences (chock and log) were infested with native cats"* and an anonymous writer recalled – *"It is 45 years since they were abundant in the Warrnambool district…55 years ago, I was offered a bonus of 0.5 d a scalp…to trap these native cats…but I caught so many that the contract was ended."*[603]

When David Fleay, then Director of Healesville Sanctuary, photographed his child with young Eastern Quolls in 1931, he was aware that their last western district, mainland stronghold was at South Dreeite where they were living in stone fences and rocky outcrops. By the time Eastern Quoll were proclaimed protected in 1935, it was too late.

The reasons for their extinction in Victoria remain unclear but competition with, and predation by, the introduced Red Fox (*Vulpes vulpes*) is likely to have been a significant factor along with persecution by humans.

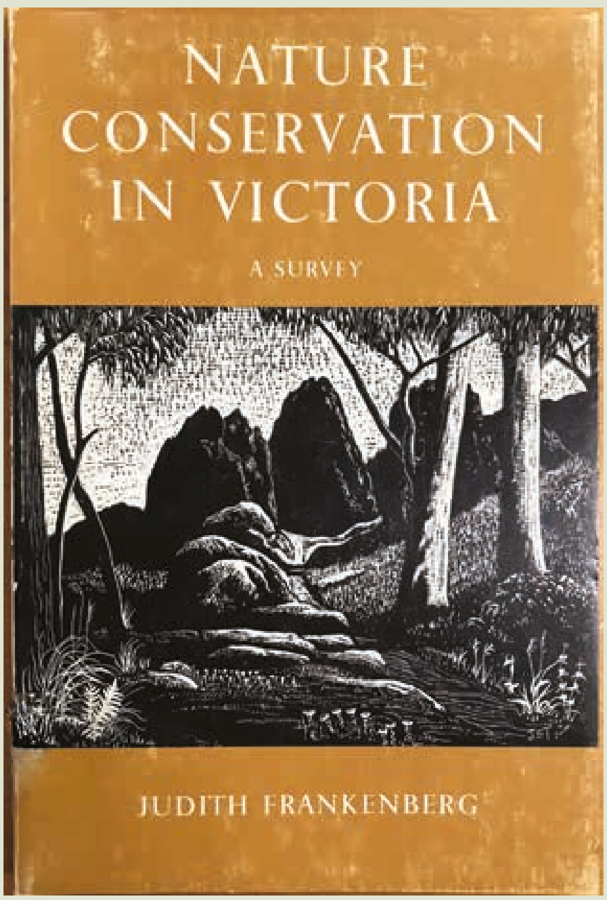
Fortunately, Eastern Quoll persist in Tasmania and perhaps one day we will see them invited to return to the mainland.

Putting aside the economic importance of nature in protecting the water we drink, in pollinating the food we eat and inspiring the medicines that maintain our health, our experience of life is diminished when such creatures are absent.

Quoll handbag. © John Seebeck.

Judith Frankenberg – the first statewide review of nature conservation

IN 1972, the first ever assessment of the conservation status of Victoria's natural environment was published. The author was Judith Frankenberg and she was working for a community organisation, the Victorian National Parks Association. Judith systematically categorised the State's vegetation into 62 'alliances' and assessed which alliances were not protected in the meagre reserve system of the time that covered just 1.2% of the State. She compiled the first statewide list of flora and vertebrate fauna and found that well over one third were not recorded in any reserve.[604] Today the reserve system covers around 17% of the land area and 5% of the waters of the State of Victoria.



Where we could go

IF IT'S not working, things need to change. Here are a few ideas about what every person in Victoria has the capacity to contribute to nature. These are additional to the ongoing need for practices such as protecting and restoring habitat and managing pest plants and animals.

Firstly, we can embrace nature as an essential and wonderful part of life. We need to see ourselves as part of nature, not distinct from it. We need to stop looking to the European landscape for inspiration and connection and instead value our unique natural heritage. We need to accept the difficulties as well as the benefits. It will involve difficult decisions (e.g., how to manage over-abundant species, how to live with native species that cause damage). We can transition toward an attitude and practice of living with Australia's nature.

Turning people on to nature

In our society there is a diversity of views about nature. We know very little about why some people love it and others may not. Some of the things that have turned people on to nature include:

Experiences in the bush – these experiences may have come about in many ways including bushwalking, hunting, fishing, scouting, visiting family and friends etc.

The associated feeling – that the natural environment contributes to a 'sense of place', is mysterious, defines us, is spiritual, offers more to learn etc.

A champion or mentor – who provided inspiration, insight, encouragement and guidance. The champion may have been a professor, teacher, family friend or celebrity.

Understanding – the nature of ecosystems and species, their diversity and uniqueness (e.g., through books, close observation of specimens, collecting, keeping, interacting), and knowing the facts of how nature operates.

To my mind, the above is a useful framework to guide educational programs. Imagine every citizen pledging to assist nature as best they could during their lifetime. This would be an admirable first step outcome from our education system. Let's assume they did. What are practical actions anyone could take given we are not all directly involved with conserving nature?

Acting for nature

Practical ways for the general community to make a contribution to nature include:

Giving money – donating to organisations that support nature by undertaking work that protects habitat and species.

Giving time – volunteering to help environmental projects and organisations, particularly those that result in improved wildlife habitat.

Advocating on behalf of nature (politically) by supporting advocacy groups and exercising the right to lobby politicians and vote at elections. Wild animals don't get to vote, we do.

Managing your land to include nature – there are many schemes offering support including Land for Wildlife and Trust for Nature.

Living and working sustainably – there is an enormous amount to be done in this space. Find out what actions you could take that would make the most difference for nature and request to understand why.

Future landscapes

Finally, we need a powerful plan for where and how nature can fit in to our contested land and sea scapes. These ideas are too big to adequately cover in this book so I leave you to contemplate them and do your own research. Biodiversity strategies are regularly published by governments but universally fail to consider the real costs of implementing their actions dooming them to fail before they get underway.

A genuine connection with nature is enriching, humbling, captivating, uplifting, fascinating and meets our innate need to explore and be part of the wondrous system of which we are a part.

Nature provides the orchestral background to life. It is the setting in which humans evolved and in which we remain embedded.

The family of Australian botanist Jean Galbraith[605] picnicking on the Tyers River about 1916 with violin and books for entertainment. Experiences in nature seem to provide humans with an innate need – the smells, the sense of adventure, the endless variety, the mystical, the inspiring.

Keeping wildlife

As for keeping wildlife, now that I understand the complex physical and emotional needs of wild animals, I only wish that they live wild and free. I enjoy going to their habitats rather than seeking to imitate them at home.

However, if you wish to keep animals in captivity then joining a club with expertise in their husbandry and following the relevant guidelines for keeping animals in captivity will help to ensure their health and wellbeing. You should check with the relevant government department whether a licence or permit is required.

See http://agriculture.vic.gov.au/pets/other-pets; https://www.wildlife.vic.gov.au/keeping-and-trading-wildlife/private-wildlife-licences

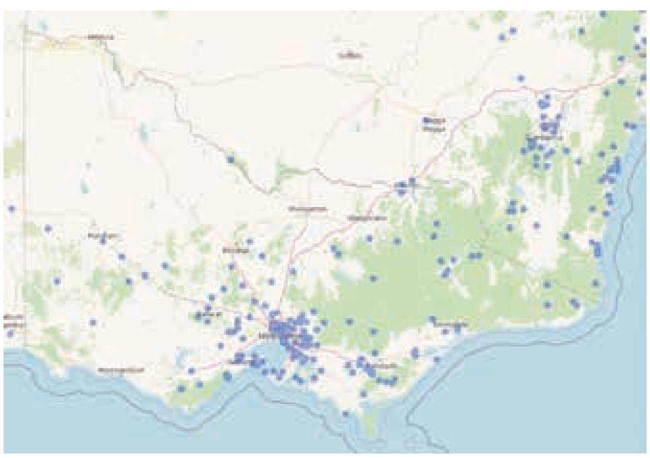
Mountain Ash – a forest giant, the tallest-growing flowering plant on Earth and on Melbourne's 'doorstep'. Source: DELWP.

Now I know a bit

WITH THE passage of time and gained experience, I have learnt a great deal more about ecology and the lives of organisms than when I kept animals as a child.

The shore crabs I collected died because I failed to maintain the tidal environment they live in; they drowned. A search of the literature suggests that we know very little more about this crab species than when I was a student. Detailed studies of most organisms are lacking. **I have learnt that there is much more to learn about nature.**

Look at this incredible creature. Beset by habitat loss, probably disoriented by city lights and attacked by introduced wasps, its fate is in our hands. © Liz Tasker.



Nineteen Victorian Emperor Gum Moth records were added to the Atlas of Living Australia in the first eight months of 2021, a sign that the species still occurs in Victoria.

The Emperor Gum Moth (*Opodiphthera eucalypti*) caterpillars I watched turn into giant moths seem to have declined in the bushland that I frequented around Melbourne. This may be due to loss of habitat and increasing suburban street lighting, which can disorient moths, or introduced species such as the European Wasp that kills the caterpillars. **I have learnt that we have lost and are losing species rapidly and sometimes without knowing it and that we need to do better than just chart the decline of a species and instead actively work to recover them. This requires realistic resources.**

The tadpoles I watched turning into frogs also drowned without the option of getting out of water as they changed to air-breathing frogs. They would have also starved as tadpole and frog diets are quite different. As a child I gave no thought to whether they came from cool or warm water or other factors they may require. **A key learning has been that in order to maintain healthy ecosystems, we must understand the needs of organisms from their perspective.**

This is often quite different to how humans see the world. We prefer tidy, park-like environments that allow us to scan for risks. Many organisms like the 'messiness' that we seek to tidy up which, to them, is their shelter from predators, their food source, their breeding habitat and so forth.

I have learnt that all organisms, including humans, live as part of ecosystems; that everything is connected and that we must deal with whole systems. We are embedded in nature and nature is embedded in us. Long ago we set out on an evolutionary journey as conjoined partners. It follows that the more we harm nature, the more we harm ourselves. The destruction of the Earth's ecosystems puts humans at great risk.

I have learnt that many organisms and ecosystems are much older than I imagined and thus so much more difficult to replace.

I have learnt that most of the species we live with are found nowhere else so we have a role as their primary custodians.

I have learnt that we have made huge mistakes through misunderstanding nature. We need to respect the value of science and objective means of increasing our knowledge.

Lastly, through our own dominance of the planet **I have learnt that I and my fellow citizens have the capacity to accept or reject a role as a steward of nature.** If we want the immense benefits of having nature around then we must each make a personal and collective contribution.

Recommended reading

Comprehensive ecosystem accounts

River Red Gum – Colloff, M. (2014). Flooded Forest and Desert Creek: ecology and history of the River Red Gum. CSIRO Publishing. Forest Pattern and Ecological Process.

Mallee – Noble, J.C. and Bradstock, R.A. (1989) (eds). *Mediterranean Landscapes in Australia: Mallee ecosystems and their management*. CSIRO Australia.

Native grasslands – Morgan, J.W. and Williams, N.S.G. (2015). The ecology and dynamics of temperate native grasslands in south-eastern Australia. In Land of *Sweeping Plains: managing and restoring the native grasslands of south-eastern Australia.* Edited by Nicholas S.G. Williams, Adrian Marshall and John W. Morgan. CSIRO Publishing, Clayton South.

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Geology of south-eastern Australia – Costermans, L. (in preparation).

Species identification (statewide)

Plants

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Plant websites:

Atlas of Living Australia – https://www.ala.org.au/

Royal Botanic Gardens Vicflora database – https://vicflora.rbg.vic.gov.au/

Victorian Biodiversity Atlas – https://vba.dse.vic.gov.au/vba/#/

INaturalist – for recording your observations and help with identifications. https://www.inaturalist.org/

Viridans www.viridans.com.au

Mosses and fungi

Meagher, D., Fuhrer, B., Australian Biological Resources Study, & Field Naturalists' Club of Victoria. (2003). *A field guide to the mosses & allied plants of Southern Australia* / D.A. Meagher, B.A. Fuhrer. (Flora of Australia supplementary series;20). Canberra: Blackburn, Vic.: Australian Biological Resources Study; Field Naturalists Club of Victoria.

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Grey, P. and E. (2020) *Fungi Down Under: the FungiMap Guide to Australian fungi*. Fungimap Inc.

Fungimap – https://fungimap.org.au/ to record your sightings.

Animals

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Beetles and spiders of Melbourne.
https://www.flickr.com/groups/2261616@N23/pool/tags/coleoptera/

Marine

Port Phillip Bay Taxonomic Toolkit
https://portphillipmarinelife.net.au/

Hardy's Internet Guide to Marine Gastropods
https://conchology.be/?t=261

There are numerous regional guides to plants and animals.

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The Tawny Frogmouth (*Podargus strigoides)* is common in urban areas of Melbourne. It mainly eats invertebrates at night. Their daytime roost is usually a dead tree branch where they are well camouflaged. They rarely stay more than a few days in one tree.
© Juliet Lowther.

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Tarra-Bulga National Park © Stephen Platt


VICTORIA

This book is written for people who have a keen interest in nature and want to know more about it. It assumes very limited prior knowledge of the natural world. It's a book about how living things are connected with their environments and each other in the State of Victoria, Australia.