'Bugs, Beasts and Biodiversity'

Exploring Biodiversity in the South-west of Western Australia

An Environmental Education Resource for Secondary Schools

Author: Jean-Paul Orsini
Editor: Ross Mars

Gordon Reid FOUNDATION
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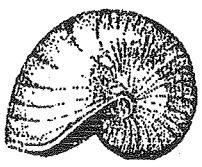

Australian Association for Environmental Education (WA) Inc.

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This resource can be downloaded from the website of the Australian Association for Environmental Education (WA) Inc: http://www.apea.asn.au/~aaee

Foreword

What is 'Bugs, Beasts and Biodiversity'?

'Bugs, Beasts and Biodiversity' is an education resource that provides a window into the rich biological diversity of the South-west of Western Australia. It presents practical case studies to help students explore the complex interconnections between various life forms in our environment. The material provides examples of biodiversity in the South-west that are directly relevant to the students' surroundings.

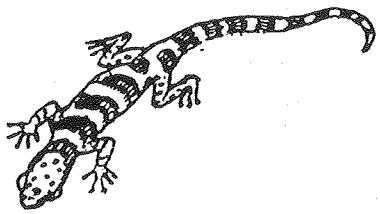
This education resource was written for lower secondary school students and teachers. However, it can be used by both upper primary and upper secondary school students and teachers, and more generally by environmental educators.

The package contains 8 sections:

(a) a general introduction, which introduces the concept of biodiversity and its value, with examples that can be used in the classroom as a starting point for discussion.

(b) six case studies which cover a wide range of terrestrial, estuarine and marine environments and species. These are:

- Woylies, Fungi and the Jarrah Forest;
- Mistletoe, Mistletoebirds, Butterflies and Ants;
- Honey Possums and Wildflowers;
- Vanishing Carnaby's Cockatoos;
- Estuaries, Mudflats and Migratory Waders;
- Seagrass Meadows: Supporting the Coastal Web of Life.

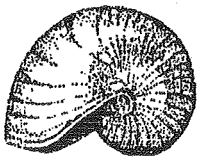


Each case study focuses on one or several species and their web of life, emphasising the interconnections between different life forms, the influence of human impacts, and conservation and social aspects. Each case study includes:

- background information and description of the case study;
- a species list;
- student activities in and outside the classroom;
- a list of references for further reading;
- a list of contacts and websites;
- a glossary.

(c) an appendix, which includes additional references, contacts and websites, as well as a reference to the new Student Outcome Statements produced by the Education Department of Western Australia.

Contents



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An Introduction to Biodiversity

Biodiversity, the Variety of Life on Earth

What is Biodiversity?

Biodiversity represents the sum of all living organisms, such as plants, animals and micro-organisms, their genetic variations and their interconnections within complex ecosystems.

Biodiversity exists everywhere: in forests, mountains, deserts, lakes, rivers and oceans. It is present in cities, houses and backyards, on farms and in any human modified environment, as well as around our bodies, on our skin and in our internal organs.

Biodiversity is the variety of life forms which exist on the Earth.

Biodiversity includes not only the plants and animals that we see around us (including ourselves), but also the myriad of microscopic organisms that inhabit our environment, such as fungi, algae, bacteria and viruses.

Most of the Earth's biodiversity consists of a large number of invertebrates, fungi, bacteria and non-flowering plants. Vertebrate animals and flowering plants represent only a small fraction of the total biodiversity, probably less than 1% in number of all species on Earth.

Biodiversity: More Than What Meets the Eye

The estimated total number of species on the Earth keeps being revised upwards as our knowledge of natural environments improves.

A recent study by two Perth scientists, Dr H. Recher and Dr. J. Majer, found that the canopy of two Western Australian species of eucalypts, the jarrah and the marri, is home for as many as 750 different species of insects, spiders and mites. Given that there are 750 species of eucalypts in Australia, the scientists estimate that there may be over 250,000 different species of invertebrates living on eucalypts alone, far more than what anyone would have imagined.

We have studied only a small amount of life on Earth.

In the light of this discovery, they have speculated that the total number of species living in Australia could be as high as one million, and the total number of species on Earth could be raised from 30 million to 100 million. These estimates give some indication of how little we know about the biodiversity around us.

The Origin of Biodiversity

The variety of life is the result of over four billion years of evolution since the appearance of the first self-reproducing cells on Earth. Early life was microscopic and appeared in the warm oceans that covered the Earth. Visible life forms appeared only 'fairly recently', about 570 million years ago.

One of the major extinction events occurred around 65 million years ago when the dinosaurs disappeared after having been the main vertebrate life form for 140 million years. The rise of flowering plants and mammals started around that time and has shaped the world in which we live today.

Extinction events have wiped out many species.

The Global Extinction Crisis

Many species of plants and animals are now under threat of extinction; many have already become extinct. The major extinction event that is occurring at present is as dramatic and sudden as when the dinosaurs became extinct. It has the potential to eliminate a large proportion of the Earth's biodiversity within the next few decades. Unlike any previous extinction event in the Earth's history, this event has been triggered by one species: *Homo sapiens* (humans). Scientists estimate that the Earth is losing species 1000 to 10,000 times faster now than at any other time in its history.

Humans are causing the extinction of many species.

This extinction crisis is likely to accelerate as the Earth's living resources become increasingly depleted and as we further modify the Earth's environment. As a biological species, we are an integral part of the Earth's biodiversity and cannot dissociate ourselves from it. Our evolutionary past and future are linked with the Earth's biodiversity.

Biodiversity and Australia's Web of Life

Australia: A World Centre of Biodiversity

Australia is one of the 12 'megadiverse' countries which together are home to 70% of all of the world's species. It is the only one of these countries which includes a large temperate climatic zone. All the others - China, Brazil, Colombia, Ecuador, Peru, Mexico, Zaire, Madagascar, India, Indonesia, Malaysia - are in the tropics. Not only is Australia rich in species, but most of the plants and animals that inhabit Australia do not occur anywhere else: they are called 'endemics'.

Organisms which are unique to an area are said to be 'endemic' to that region.

Biodiversity in the South-west: Ancient, Rich and Unique

The South-west corner of Western Australia, an area defined here as west of a line between Shark Bay and Esperance, stands apart for its ancient, rich and unique biodiversity. Much of the fauna and flora remains to be studied and there are still many new species to be discovered, even large, conspicuous animals and plants. For example, a new species of frog with a bright blue and orange belly, the Sunset Frog, *Spicospina flammocaerulea*, was recently discovered in a peat swamp north of Walpole.

It is estimated that up to 3000 species of plants still remain to be discovered in the South-west, and only 5 to 10% of the larger fungi have been named by scientists. The knowledge of the ecology of most of the species occurring in the South-west is incomplete.

Many of the species in our South-west are still to be discovered.

Ancient

Going Back to the Beginning of Life on Earth

The South-west of Western Australia contains some of the most ancient landscapes, rock formations, soils and fossils known in the world; it is an amazing fragment of the Earth's long history.

Stromatolites, made up of a type of tiny organism invisible to the naked eye, are the oldest life form known on the planet. It is amazing to know that stromatolites can be found living at several locations in the South-west of Western Australia, including Government House Lake on Rottnest Island,

Stromatolites are very ancient organisms which go back to the beginning of life on Earth.

Lake Clifton near Mandurah and Hamelin Pool in Shark Bay. They are preserved as fossils in the iron ore rocks of the Pilbara, an arid region in the north of Western Australia.

Another example of a 'living fossil' is the *Peripatus*, an ancient link between Annelids (worms) and Arthropods (a group that includes spiders, insects and molluscs) that is related to a 540 million-year-old fossil. Two species of *Peripatus* still exist in the wet South-west corner of Western Australia.

Gondwanan Fauna and Flora: Relicts from the Past

Australia was once part of an ancient continent called 'Gondwana'.

Gondwana was an ancient continent that existed 200 million years ago in the southern hemisphere. As it drifted across the Earth's surface, it broke up into several land masses that later became Australia, Antarctica, South America, Africa, Madagascar and India. The South-west is a refuge for species which have survived from the time when Australia was part of Gondwana.

Some of the species of Gondwanan origin still found in the South-west are:

- the zamia, which is part of the cycad family that formed extensive forests at the time of the dinosaurs;
- plants of the banksia family that are believed to have originated in the rainforests of Gondwana. The banksia family is called Proteaceae after the proteas, a group of plants with spectacular flowers from South Africa to which banksias are related;
- trapdoor spiders, which build elaborate silky doors at the entrance of their burrows; and
- the primitive freshwater salamanderfish, which can survive for several months without food or water by burrowing into the mud.

Many of our plants and animals are of Gondwanan origin.

Rich

Western Australia contains a high degree of biodiversity in its flora and fauna.

It is estimated that Western Australian biodiversity contains between one third and one half of Australia's total biodiversity. A large part of Western Australia's biodiversity is found in the South-west, the area between Shark Bay and Esperance. This area is exceptionally rich in plants, with an estimated 6000 to 8000 species. The richness of the South-west flora is comparable to that of tropical forests.

Back from the Brink

The Noisy Scrub-bird, *Atrichornis clamosus*, had not been seen since 1869 and was considered extinct when it was rediscovered in the early 1960s at Two Peoples Bay, on the South Coast near Albany. The area has now become a nature reserve and the numbers of Noisy Scrub-birds have been greatly increased through careful habitat management and a successful translocation program: Noisy Scrub-birds have been captured and released to other suitable areas where they have established new breeding populations. The number of Noisy Scrub-birds has increased 25-fold in the last 20 years.

The endangered Gilbert's Potoroo and Noisy Scrub-bird are found at Two Peoples Bay near Albany.

The Gilbert's Potoroo, *Potorous tridactylus gilberti*, was rediscovered also at Two Peoples Bay in 1994, after having been considered extinct for 125 years. There are only 20 individuals known in the wild. A captive breeding population has been established at the site, but the species is dangerously close to extinction.

Both species were widely distributed across the South-west before European settlement.

Group	Number of species described so far	Estimate of total species	Number of species presumed extinct in last 200 years	Number of species which are threatened
Mammals	149	185	10	31 terrestrial 5 marine
Birds	510	516	2	18 species and 13 subspecies
Reptiles	440	484	0	8 species and 3 subspecies
Amphibians	77	83	0	3
Fish	1600	1900	0	2
Vascular plants	8000	12000	25	321
Non-vascular plants	1500	100,000 to 200,000	unknown	unknown

Table 1. Number of extinct and endangered species in Western Australia.
Source: WA State of the Environment Report (1998), page 23.

Vascular plants: contain conducting vessels for water, minerals and nutrients. e.g. flowering plants

Non-vascular plants: do not have vascular tissue to transport materials throughout the plant. e.g. mosses and liverworts.

Unique

The flora of the South-west of Western Australia has a high proportion of endemic species: 80% of all plant species in the South-west do not occur anywhere else in the world.

The South-west fauna is just as unique. Marsupials like the Brush Wallaby, the Quokka, the Gilbert's Potoroo, the Honey Possum, the Dibbler and the Western Ringtail Possum occur only in the South-west of Western Australia. Similarly, many reptiles, frogs, insects and other invertebrates are unique to the South-west.

The South-west's Biodiversity Under Threat

Biodiversity in South-western Australia has suffered a major decline in the last 200 years. Almost half of the mammals that used to occur in the Wheatbelt are now extinct in that region, and several species of birds and mammals have become extinct from the South-west forests. The range of many species has greatly diminished, sometimes to the point that they are found only in small isolated populations.

Many animal species in the wheatbelt and the SW forests have become extinct.

South-western Australia has become a refuge against extinction for several mammal species, such as the Numbat, Chuditch and Woylie, which used to occur throughout Australia, but have dramatically declined over the last 200 years.

As 80 to 90% of the natural vegetation has been cleared in the Wheatbelt, the rich animal and plant life relies on the small remaining patches of habitat to survive, and their long-term future is in doubt.

Conocurvone and the AIDS Virus

Conocurvone, a compound derived from the Western Australian Plume Smokebush, is currently being investigated for use as a drug against the AIDS virus. The Plume Smokebush, *Conospermum incurvum*, is a handsome native plant of the banksia family that occurs only in the South-west of Western Australia. The rich flora of the South-west has great potential for providing modern medicine with compounds previously unknown to science.

Biodiversity, the Earth's Life Support System

Biological Wealth and Human Needs

From the diversity of life on Earth, we harvest natural resources such as fish and timber. We grow crops and livestock, which were selected from wild plants and animals over thousands of years. Using the biological diversity around us, we make clothes from cotton, wool and other natural fibres, construct houses and adapt to a continuously changing environment.

Many plants contain medicines which can be used to treat disease.

Almost half the medicinal drugs used in western countries are derived from plants and animals. The great majority of people on Earth rely on natural medicines to protect themselves from diseases. Noongars, the Aboriginal people who inhabited much of the South-west, know of many natural medicines in their environment. For example, the sap of the Marri (red gum) was known to have antiseptic properties.

Quinine, a substance derived from the bark of a South American tree, was known by Aztec Indians to reduce fever. It was brought back by missionaries from Peru to Europe as early as 1640 and was the main remedy for malaria until the 1970s. The antibiotic action of Penicillin, a substance found in a green mould*, *Penicillium notatum*, was discovered in 1928. It has revolutionised modern medicine.

The Economic Value of Biodiversity

The economic value of biodiversity in Australia is many billions of dollars.

The well-being of human societies relies on the conservation of biodiversity. Almost all human activities - agriculture, industry, transport, energy production, recreation and various goods and services, including provision of food, shelter and water - rely on biodiversity. Various techniques are used by economists to give natural resources a dollar value. The economic value of biodiversity for the Australian community has been estimated to be between 840 and 2000 billion dollars.

Biodiversity needs to be managed carefully.

Biodiversity provides rich resources for the Australian economy. Careful management of Australia's biodiversity will help provide a more secure access to natural resources for future generations. In economic terms, biodiversity is our capital; it makes sense to live off the interest and carefully manage and conserve this precious asset.

* Moulds are widespread fungal growths that are involved in the decomposition of dead organic matter.

Dryland Salinity, the Cost of Losing Biodiversity

The Western Australian Wheatbelt is threatened by rising salinity after the clearing of 80 to 90% of its native vegetation. It has been estimated that it would cost over $3 billion over the next ten years to attempt to control the spread of salinity on farmland.

We now realise that the native bush which was in the way of agricultural development was providing us with free 'ecosystem services' which are expensive to replace.

Restoring biodiversity is very costly.

Ecosystem Services

Biodiversity provides human societies with free services that preserve the essential qualities of our environment on which our life depends. These include:

- Earth's climate and the oxygen in the air which supports the planet's ecosystems and allows us to breathe;
- clean water, fertile soils and bountiful oceans;
- the control of pests and viruses;
- the cleaning up of our wastes; and
- the pollination of plants, including those on which we depend directly for food.

Biodiversity, the Source of the Earth's Atmosphere

Biodiversity has been described as the Earth's life support system. Seventy per cent of the oxygen in the atmosphere is produced from the ocean's minute phytoplankton. Most of the rest comes from tropical and temperate forests and, more generally, the Earth's vegetation cover. The atmosphere surrounding the Earth shapes its global climate, which in turn determines the distribution of life on the planet.

Most of the oxygen in the atmosphere is produced by micro-algae in the oceans and forests on land.

Global Warming: A Threat to the Planet's Biodiversity

The effect of human activities can be felt at a planetary scale: global warming of the atmosphere is due to the excessive production of greenhouse gases and the decrease in land vegetation cover. These gases include carbon dioxide, methane and other gases such as chlorofluoro-carbons (or CFCs) found in air pollution. Greenhouse gases come from the burning of fossil fuels (coal, diesel, petrol, natural gas) in cities and industrial areas, the burning of native vegetation during clearing or forestry operations and the production of methane gases from the digestion of animals and from rotting vegetation.

Greenhouse gases trap heat in the atmosphere, which results in global warming.

There are already signs that this overall increase in temperature may result in a significant rise in ocean levels in the future. Low-lying island nations like the Maldives in the Indian Ocean or Nauru in the Pacific now consider their own long-term existence to be at risk if these predictions are realised.

Many species and many ecosystems are likely to be threatened by global warming. The warming of the Earth's atmosphere means that the habitat of many native species may diminish, threatening them with extinction. Agriculture may also be affected by global warming, with crops being affected by drought and diseases, and whole regions becoming unsuitable for certain crops.

Global warming may result in the extinction of more species.

The Wise Use of Biodiversity

In the process of using biological diversity for our needs, we have modified our environment to the point where the existence of many of the Earth's species and ecosystems is threatened. Old-growth forests are disappearing, ocean life is depleted, and land continues to be cleared for human activities. As the Earth's population increases, the Earth's natural resources are being stretched to the limit.

Sustainable Use: Can We Achieve It?

Sustainability is the wise use of natural resources. Sustainability is making sure that what we do will not damage or diminish the biological diversity on which our survival depends. There is a general lack of agreement between industry, governments, scientists, conservation and other community organisations, about which human activities can be considered ecologically sustainable, or indeed whether *any* human activity can be considered sustainable.

Sustainability is th wise use of resource so that bioversity i not adversely af fected.

Ecologically sustainable development means 'using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased.' From *Australia's National Strategy for Ecologically Sustainable Development* (1992).

Indigenous Australians: the Last 40-60,000 Years

Wild resources have been used by people from the early times of humanity. Aboriginal people, during the 40-60,000 years since their arrival, have influenced the Australian continent through their use of fire, and their hunting and collecting.

Aborigines have ha a major influence o the Australian envir onment.

Aboriginal people were nomadic and their influence on the Australian landscape was guided by traditional customs that seemed to have generally prevented an overuse of natural resources. Water holes were looked after and these provided fresh water not only for the human temporary residents, but also for kangaroos, birds and other animals that inhabited the area. Fire was used regularly as a tool for managing vegetation and wildlife.

Recent Settlers: the Last 200 Years

The colonisation of Australia over the last 200 years has had a far greater and more dramatic impact on the continent's biodiversity. Many types of natural environments have been greatly modified, often irreversibly.

The biodiversity in Australia has beer seriously reduced after European settlement.

Many species of fauna and flora have become extinct, and many more are endangered. Australia has the unfortunate record of having the highest number of mammal extinctions in the world.

The Extinction of Megafauna

Giant kangaroos, wallabies, wombats, the huge tapir-like *Diprotodon*, giant flightless birds, a marsupial lion and a giant python existed in Australia until at least 35,000 years ago. Their memory is still alive in the Dreamtime legends of Aboriginal people around Australia. It is not clear whether these species were hunted to extinction by early Aboriginal Australians, or whether extinction was the result of a lack of food through climate change, or a combination of both factors.

Megafauna = giant animals.

Most scientists would agree that there is no single cause for the ongoing loss of Australian biodiversity. There is an increasing awareness now that most human activities have some adverse impact on biodiversity.

These impacts are due to a combination of factors that include agriculture (particularly the impacts of clearing, overgrazing and salinity), weeds and exotic animals (such as rabbits, foxes and cats), frequent fires, logging, fishing, mining, tourism and urbanisation.

Many factors have contributed to the continual loss of biodiversity in Australia.

Biodiversity and Ethics

A range of people support the view that all species on Earth have a right to exist for their own sake. They say that we must protect biodiversity not only for its value to us, but also for its intrinsic value and for the beauty that enriches our lives.

All species have a right to exist.

Even though we may never be directly affected if a particular animal, plant or ecosystem disappears, most people would feel sad knowing that they have gone for ever.

What Can We Do to Save Biodiversity?

Can We Restore Biodiversity?

Not only is it very expensive to restore natural environments once they have been degraded, but restoring biodiversity may often be difficult, if not impossible. It is far more effective to conserve existing biodiversity than to attempt to restore it once it has been degraded.

It is better to conserve biodiversity than to restore it.

Restoration of degraded natural ecosystems can be achieved by revegetation with local native species and translocation of various animals. However, this process can only hope to restore a fraction of the original ecosystems. By careful and planned restoration, some of the ecosystem complexity can eventually be returned.

Revegetation helps to restore natural environments.

The 1992 Earth Summit on Biodiversity

The 1992 Earth Summit, held in Rio de Janeiro (Brazil), assembled the largest gathering of heads of state, experts and non-government organisations in recent history. The conference discussed urgent measures to address the global decline of biodiversity and resulted in the signing of the *Convention on Biological Diversity*.

Australia has ratified the international Convention on Biodiversity.

The Convention was ratified by Australia the following year. It is being primarily implemented in Australia through the *National Strategy for the Conservation of Australia's Biological Diversity*, which was released in 1996.

Sustainable Living

Conservation of biodiversity involves a coordinated effort by government, industry, land managers, communities and individuals. However, as much as we should expect government to protect biodiversity and provide adequate funding for biodiversity conservation, we can also take personal action to make a difference. We can all help conserve biodiversity.

As consumers, we can reduce our use of natural resources by recycling, buying recycled or second-hand goods, choosing reusable items rather than disposable ones, and using fully renewable resources (such as sustainable plantations of native Australian and exotic timbers).

We need to reduce our consumption of the Earth's resources.

As environmentally-aware citizens, we can reduce household waste by composting, use public transport or cycle rather than drive, adopt a patch of native bushland, control weeds and exotic animals, replant native species, and conserve remnant vegetation to reduce salinity and soil erosion.

By becoming conscious of our use of resources and energy, and acting to reduce these, we may reach a balance in our fragile environment. Without respect and caution, we will be faced with a crisis which future generations will have great difficulty in overcoming.

We need to take better care of our environment.

Suggested Activities

Biodiversity: Why Should We Care?

This activity, which usually takes a couple of lessons, enables students to recognise and explain the concept of interdependence.

a. Brainstorm all of the living organisms that can be found around the school. Discuss grouping these organisms in a simple classification system.

b. Make a card for each life form listed on the board, remembering that invertebrates make up most of the Earth's biodiversity and should have most cards. There should only be one or two cards allocated for vertebrates in the class set.

c. Students move into groups, each student representing one organism. Each group should reflect the approximate ratio of invertebrates to vertebrates to flowering plants and so on. Students should form a circle, holding hands. Note that a circle is closed and that all people are linked. Ask students to take one step in and to link arms behind each other. Then instruct students to lean back as far as they can, making sure that everyone is supported by the linked arms to demonstrate the interlinking of all species.

d. Teacher then "removes" one species of organisms from the circle. Repeat the above interlinking activity, but students do not link arms across gaps created by those who have been removed.

e. Discuss the observations made by students about the effect of the removal of one group of organisms. Students can also discuss the "links" or forms of interdependence between the component species of their circles. This exercise could be repeated several times to deepen students understanding of the concept.

f. Students then to write, in their own words, what biodiversity means and why it is being studied.

g. Compare several of the written definitions in class and students to modify them as required.

Case Study Teacher/Student Role Swap (applies to all case studies)

This activity enables students to select the Case Study that most interests them and to become "teachers" to their peers. Students should work in groups of no more than four to complete the work.

Provide a series of pictures of the various types of animals, insects and plants mentioned in the Case Studies. Students select the picture that most interests them. This picture becomes the focus of their research.

The groups are to become "experts" on their particular part of the Case Study using the information provided and additional research utilising some of the resources suggested in the package.

Using the information they have gathered, students should draw diagrams, learn the vocabulary and create a worksheet for other students to complete. (Teachers will need to guide students on the production of simple, clear and effective worksheets.)

After an agreed time-frame, the groups will then present their part of the case study to the rest of the class.

Following each presentation, engage students in a game of 'Verbal Basketball' to evaluate their learning and enable the concepts to be verbalised.

- Divide the group into two teams.
- Toss a coin to decide who starts.
- The winning team is the answering team.
- Students on the teaching team ask questions based on the worksheet - a different person is asked each question.
- The 'ball' is passed whenever a correct answer is given. This team then becomes the questioning team.
- It is 'intercepted' when the correct answer is not given by one team and the first person from the second team answers it correctly.
- A 'foul' occurs when the answer is called out by someone other than the person being asked.
- A 'goal' is scored for every three correctly answered questions.

Following the presentation of all of the Case Studies, students discuss the concepts they have learned - in particular, focussing on the nature of biodiversity and its implications with a view to suggesting practical ways that they can contribute to protecting biodiversity in Western Australia.

Application to the Student Outcome Statements

Science - Life and Living

Society and Environment - Investigation, Communication and Participation (Processing and Interpreting Information); Place and Space (People and Places, Care of Places); Natural and Social Systems (Natural Syustems)

English - Reading (Contextual Understanding, Use of Texts); Speaking and Listening (Processes and Strategies, Use of Texts); Writing (Contextual Understanding)

Further Reading

Books

Beattie, A. J. (Ed.) (1995). 'Biodiversity - Australia's Living Wealth'. Reed Books, Sydney.

CSIRO. (1996). 'Australia: State of the Environment 1996' Report. CSIRO Publishing, Collingwood, Victoria. Also available on CD-ROM from the Community Information Unit, Environment Australia.

Hussey, B. M. J. and Wallace, K. J. (1993). 'Managing Your Bushland'. Department of Conservation and Land Management, Como.

Isaacs, J. (Ed.) (1980). 'Australian Dreaming: 40,000 years of Aboriginal History'. Ure Smith Press, Sydney.

White, M. E. (1990). 'The Nature of Hidden Worlds'. Reed Books, Sydney.

Publications Available on Request

DEP. (1998). 'Maintaining Biodiversity', State of the Environment Report Western Australia, pp. 19-21 (1998). Department of Environmental Protection, Perth. Available on the website:

http://www.environ.wa.gov.au/pubs/soe/soe7.htm.

Russell, S. and Pimbert, M. (1993). 'The Diversity of Life'. WWF, Geneva. Available from WWF-Australia.

The following publications are available from the Community Information Unit, Environment Australia, Tel. (FREECALL) 1800 803 772. They are also available on-line from the website:

http://www.environment.gov.au/portfolio/esd/biodiv/what_is.html.

'Biodiversity and its Value'. Biodiversity Series, Paper No. 1 (1993).

Mummery, J. and Hardy, N. (Eds). (1994). 'Australia's biodiversity: an overview of selected significant components'. Biodiversity Series, Paper No. 2.

'Biodiversity: the Challenge'. Background Brief. 8 pp.

'National Strategy for the Conservation of Australia's Biological Diversity' (1996).

Teachers' Guide: 'Conserving Australia's Biodiversity'.

Education Resource Package containing: (a) 'Australia: State of the Environment 1996' Report - Executive Summary (47 pp.). Available on the website: http://www.environment.gov.au/epcg/soe/soe96/soeexec.html

(b) 'Australia: State of the Environment 1996' Report on CD-ROM (546 pp.), also on the website: http://www.environment.gov.au/epcg/soe/soe96/full_report/soe_acrobat.html and (c) a Teacher's Study Guide (114 pp.).

Popular Articles on Biodiversity

Beech, P. (1996). 'Adding up the species'. Geo Australasia 18 (6): 19.

Recher, H. F. and Majer, J. (1996). 'One humble gum tree: home to 1000 species'. Geo Australasia 18 (6): 20-29.

More articles are available on the following website: http://www.environment.gov.au/portfolio/esd/biodiv/articles/articles.html.

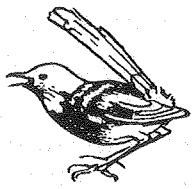
A range of brochures are also available from Environment Australia on endangered species, remnant vegetation, the marine environment, and so on.

Websites

The following websites have information on Australia's biodiversity:

Government Agencies, Universities

Biodiversity publications from Environment Australia (most are available on-line and can be downloaded):
http://www.environment.gov.au/portfolio/esd/biodiv/what_is.html
Biolink, a list of links on biodiversity in Australia and worldwide:
http://www.environment.gov.au/portfolio/esd/biodiv/biodiversity.html
Biodiversity Group, Environment Australia:
http://www.biodiversity.environment.gov.au/
Threatened Species and Communities Program, Environment Australia:
http://www.anca.gov.au/plants/threaten/
Macquarie University (NSW) biodiversity website:
http://www.bio.mq.edu.au/kcbb/biodivaus.html



School Resources Websites

School resources website produced by Environment Australia:
http://www.environment.gov.au/portfolio/education/aeen/schools.html
School resources website produced by the Community Biodiversity Network: http://www.cbn.org.au/member/cbn/context/
Webpage for the book 'Biodiversity - Australia's Living Wealth', by A. J. Beattie including the book's first chapter:
http://www.bio.mq.edu.au/kcbb/book.html

Non-government Organisations

The Community Biodiversity Network website is a very comprehensive site with links, references, documents: http://www.cbn.org.au/
The Birds Australia website includes comprehensive information on threatened Australian birds: http://www.vicnet.net.au/~birdsaus/
The Threatened Species Network website is a site on Australian threatened species and communities: http://www.nccnsw.org.au/member/tsn/

International Information Sources

The World Resources Institute is a US-base website including a section on biodiversity: http://www.wri.org/wri/biodiv/
The Website of the International Convention on Biological Diversity provides regular updates about the progress of the Convention:
http://www.unep.ch/bio/conv-e.html
The Biodiversity Conservation Information System is a site on biodiversity maintained by the IUCN (World Conservation Union):
http://www.biodiversity.org/

Contacts

The following organisations can offer information on various aspects of biodiversity.

Government and Other Agencies

Department of Conservation and Land Management, 50 Hayman Street, Como WA 6152. Tel. (08) 9334 0333.
Website: http://www.calm.wa.gov.au/

Department of Environmental Protection, Mounts Bay Road, Perth WA 6000. Tel. (08) 9222 7000. Website: http://www.environ.wa.gov.au/

Department of the Environment (Environment Australia), Community Information Unit, GPO Box 636, Canberra ACT 2601. Tel. (FREECALL) 1800 803 772. Website: http://www.dest.gov.au/

Fisheries Western Australia, 3rd Floor, SGIO Atrium, 168-170 St George's Terrace, Perth WA 6000. Tel. (08) 9482 7333.
Website: http://www.fish.wa.gov.au/

Kings Park and Botanic Garden, West Perth WA 6009. Tel. (08) 9480 3600. Website: http://www.kpbg.wa.gov.au/

Perth Zoo, Labouchere Road, South Perth WA 6151. Tel. (08) 9367 7988. Website: http://www.perthzoo.wa.gov.au/

Underwater World, Hillarys Boat Harbour, Tel. (08) 9447 7500.
Website: http://www.coralworld.com/perth/

Water and Rivers Commission, Level 2, Hyatt Centre, 3 Plain Street, East Perth WA 6004. Tel. (08) 9278 0300. Website: http://www.wrc.wa.gov.au/

Western Australian Museum, Francis Street, Perth WA 6000. Tel. (08) 9427 2700. Website: http://www.museum.wa.gov.au/

Non-government Organisations

Community Biodiversity Network, c/- Centre for Biodiversity and Conservation Research, Australian Museum, 6 College Street, Sydney NSW 2000. Tel. (02) 9380 7629. Website: http://www.cbn.org.au/

Conservation Council of Western Australia, 79 Stirling Street, Perth WA 6000. Tel. (08) 9220 0652. Website: http://www.iinet.net.au/~conswa/

Greening WA, 10-12 The Terrace, Fremantle WA 6160.
Tel. (08) 9335 8933.

Marine and Coastal Community Network, 79 Stirling Street, Perth WA 6000. Tel. (08) 9220 2662. Website: http://www.ozemail.com.au/~mccnet/

Threatened Species Network, PO Box 4010, Wembley WA 6014. Tel. (08) 9387 6444. Website: http://www.nccnsw.org.au/member/tsn/

WA Gould League, Herdsman Lake Wildlife Centre, Cnr Selby Street/ Moondyne Drive, Wembley WA 6014. Tel. (08) 9387 6079. Website: http://www.gould.schnet.edu.au/index1.htm

World Wide Fund for Nature, same contact as Threatened Species Network. Website: http://www.panda.org/resources/inthefield/country/australia/

Glossary

These definitions have been adapted from the Commonwealth State of the Environment Report (Appendix).

CFCs (chlorofluoro-carbons)

Synthetic gases commonly used in industry, home refrigerators and, prior to 1990, as a propellant gas for sprays; deplete ozone in the upper atmosphere and are powerful greenhouse gases.

Ecology

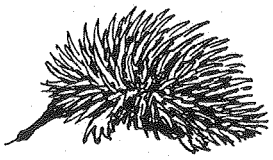
The science that seeks to understand the relationships between the various organisms in an ecosystem (see below).

Ecosystem

Term used to describe a specific environment and all the interconnections between its different parts, including animals, plants and micro-organisms.

Fauna

The animals which live in a particular region.



Flora

The plants which occur in a particular region.

Greenhouse effect

The effect resulting from human activities, such as the burning of fossil fuels and land clearing, which increase the atmospheric levels of greenhouse gases such as carbon dioxide, methane, nitrous oxide, ozone and CFCs. These gases trap heat within the atmosphere, contributing to global warming.

Habitat

The place where an animal or a plant normally lives and reproduces.

Invertebrate

Animal without a backbone, such as molluscs, insects and other arthropods.

Population

A group of individuals of the same species living in a particular place and time, generally forming a breeding unit and sharing a habitat.

Precautionary principle

Principle that states that the lack of scientific knowledge should not be used as a reason for postponing measures to prevent environmental degradation where there are threats of serious environmental damage.

Pest

An organism occurring where it is not wanted by humans (see Weed).

Refuge

Area that has been protected from environmental changes that have occurred over time and has become a haven for relict fauna or flora.

Relict

Animal or plant that has survived in an area or a region, but was much more widespread in past geological times.

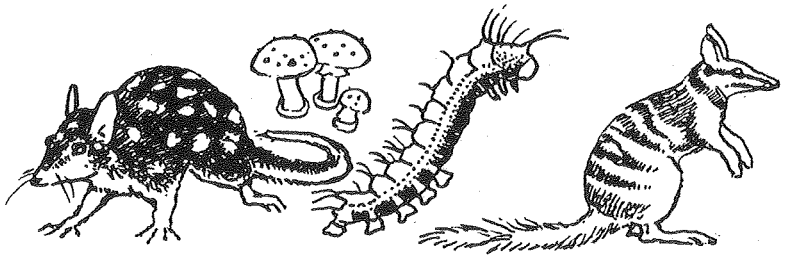
Species

A group of plants, animals or micro-organisms that have a high degree of similarity and generally can interbreed only among themselves to produce fertile offspring.

Translocation
Capture and later release of several individuals of a species for the purpose of establishing a new population in another location.

Vertebrate
An animal with a backbone composed of vertebrae: mammals, birds, reptiles, amphibians and fish.

Weed
A plant species growing where it is not wanted by humans.



Case Study 1
Woylies, Fungi and the Jarrah Forest

What is Biodiversity?

Biodiversity represents the sum of all living organisms, such as plants, animals and micro-organisms, their genetic variations and their interconnections within complex ecosystems.

Biodiversity exists everywhere: in forests, mountains, deserts, lakes, rivers and oceans. It is present in cities, houses and backyards, on farms and in any human modified environment, as well as around our bodies, on our skin and in our internal organs.

Biodiversity is the variety of life forms which exist on the earth.

Biodiversity includes not only the plants and animals that we see around us (including ourselves), but also the myriad of microscopic organisms that inhabit our environment, such as fungi, algae, bacteria and viruses.

Most of the Earth's biodiversity consists of a large number of invertebrates, fungi, bacteria and non-flowering plants. Vertebrate animals and flowering plants represent only a small fraction of the total biodiversity, probably less than 1% in number of all species on Earth.

The Jarrah Forest Web of Life

The story of the Jarrah forest web of life is about tall Jarrah and Marri trees, small shrubs, underground fungi producing tasty truffles, small kangaroo-like marsupials, dung beetles transporting spore-laden dung pellets, an enterprise in biological recycling, the introduced fox, 1080 poison, dieback, logging and fire. This story illustrates the diversity of life in the Jarrah forest and the relationships between the various species that live there.

The Jarrah forest is host to a diverse web of symbiotic relationships; that is, relationships through which two or more organisms derive a benefit from one another. In the Jarrah forest, where food, water and other resources are scarce, plants, animals and fungi have developed life strategies that are mutually beneficial.

Symbiosis is the relationship between two organisms, where both benefit.

In the course of evolution over millions of years, complex interactions have developed between plants, animals and micro-organisms as they seek to adapt to their environment.

This story shows how fragile the forest's ecological balance is and how some changes caused by humans can reduce biodiversity and impact on the whole Jarrah forest web of life.

The Woylie Story

Woylies are small marsupials that belong to a group of animals called 'Macropods' (meaning 'big-footed'), group which also includes kangaroos, wallabies, potoroos and Quokkas. Woylies are nocturnal animals which spend the day under a shrub in a nest lined with soft grass that they carry in their curled-up tail.

The Woylie is a small marsupial, related to kangaroos.

Woylies used to be widespread over two-thirds of Australia (see Figure 2).

Figure 1. Jarrah Forest Web of Life.

By the 1970s, they had disappeared from almost all of their range except for three small populations in the South-west of Western Australia: Dryandra Woodland, Tutanning Nature Reserve and the Perup-Kingston-Lake Muir area.

Woylies have become extinct in most of Australia.

Woylies and Underground Fungi

Woylies are an important part of the forest web of life. Their favourite food is truffle-like underground fungi that are abundant in the Jarrah forest. To find out which species of fungi Woylies eat, scientists have looked in the

Woylies eat underground fungi.

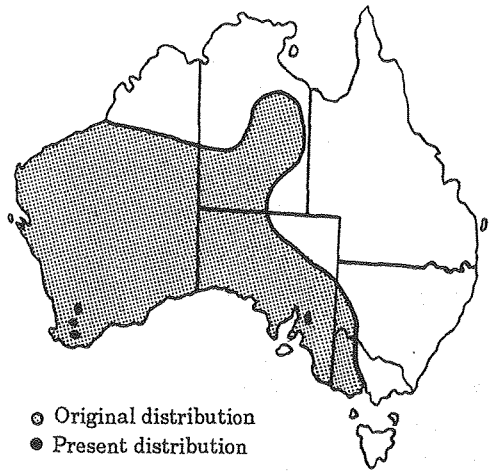


Figure 2. Distribution map of the Woylie.

Woylie's dung pellets and found fungal spores that belong to many different species of underground fungi.

Underground fungi are difficult to digest. To overcome this problem, the food is broken down into more digestible elements by bacteria that live in the Woylie's stomach. These elements are digested in the rear part of the Woylie's stomach and in the intestine. This is an example of a mutually beneficial association between bacteria and a marsupial.

Bacteria in the Woylie's stomach help break down the fungi food.

Scientists have shown that fungal spores germinate better after passing through the Woylie's digestive system. The spores are expelled in the Woylie's dung pellets which are scattered throughout the forest by the Woylie during its nocturnal activities. This helps disperse the spores of fungi around the forest floor and ensures that fungi are there to play their important part in the forest web of life.

The Woylie spreads fungal spores around the forest floor.

The Woylie
Aboriginal names: Woylie (now also common name), Bettong.
Other common names: Brush-tailed Bettong, Brush-tailed Rat-kangaroo.
Scientific name: *Bettongia penicillata.*
Family: Potoroidae.
Size: 300–380 mm (head and body length), 290–360 mm (tail).
Weight: 1.1–1.6 kg.
Diet: underground fungi, plant material, insects.
Reproduction: unlike many marsupials which breed once a year, Woylies have the ability to breed up to three times a year. Females produce one, rarely two joeys. In areas where fox control has taken place, Woylies have increased in numbers up to ten fold.

The Dung Beetle

Native dung beetles bury the Woylie's dung pellets in the soil and lay their eggs inside the dung to provide readily available food for their larvae at hatching. Thus germination of the fungal spores occurs underground close to the roots of the host plant species where fungi and trees can exchange nutrients.

Dung beetles bury the faeces or dung of animals.

Fungi: in a Kingdom of their Own

The living world can be divided into five kingdoms: Plants, Animals, Bacteria, Protista (microscopic, single-celled organisms) and Fungi. Fungi were once considered as plants, but many scientists now recognise them as a completely different life form.

Fungi are one of the five kingdoms of living things.

Delicious Truffles

For centuries, underground truffles have been keenly sought by people in Europe as a gourmet food used in some of the most highly-prized gastronomic dishes, to the point that one small handful of truffles can cost several hundreds of dollars. Dogs and pigs are specially trained to sniff out and dig up the precious fungi. In a similar way, Woylies seek out, dig up and eat the many types of Australian underground fungi.

In general, we know very little about fungi. Among the estimated 1.5 million species of fungi world-wide (four to five times the number of flowering plants), less than five per cent have received a scientific name.

The main body of fungi consists of a web of filaments called a mycelium that is below-ground, in the vegetation litter, or in rotting wood. What we know as 'fungi' (such as mushrooms and toadstools) are the types of fungi that have above-ground fruiting bodies that grow from the mycelium at certain times of the year.

The main part (body) of a fungus is called the mycelium.

Many other fungi produce a fruiting body below the ground, some of which are truffle-like; these are the ones Woylies eat. Scientists have recently discovered hundreds of species of underground fungi.

Many plants in Australia have a special association with fungi, particularly eucalypts, acacias, sheoaks and peas such as the Heartleaf Poison. This association is beneficial to both fungi and plants, as fungi supply the plants with water and nutrients gathered from the soil, while the plants produce food substances, such as sugars, necessary for fungi.

Most fungi in Australia have mutually beneficial associations with plants.

In Australia, there are an estimated 250,000 species of fungi, of which an estimated 5000 are larger fungi and the rest are microscopic fungi. Of these larger fungi, only 650 species have been scientifically described, and most of them are believed to have an association with the roots of plants.

Forest Marsupials and Underground Fungi

Several other animal species eat underground fungi.

Besides the Woylie, several other small marsupials eat underground fungi in the South-west of Western Australia; for example, the Gilbert's Potoroo, the Quenda (also called Southern Brown Bandicoot), the Quokka and the Bush Rat.

Gilbert's Potoroo has similar habits to the Woylie and feeds mainly on underground fungi. It used to be found throughout the South-west forests and was believed to be extinct in Western Australia for over 125 years until it was rediscovered in 1994 at Two Peoples Bay near Albany.

Some fungi eaters are now on the endangered species list.

The Quenda feeds only partly on underground fungi and also eats insects and plant material. Even though the Quenda is still common in some areas, it has declined over much of the Jarrah forest and has disappeared from most of the Wheatbelt. It has recently been re-introduced in the Wheatbelt at Dongolocking.

The Burrowing Bettong, now extinct on the mainland of Australia (apart from a small reintroduction area at Shark Bay), was abundant in the South-west and is believed to have consumed underground fungi.

Underground Fungi and Nutrient Recycling

Trees (such as Jarrah and Marri) and shrubs (such the Heartleaf Poison) constantly shed their leaves which are turned into humus by fungi, insects and bacteria that live in the forest litter. Humus releases nutrients that are incorporated into the soil and absorbed by the plants' root system.

Humus is produced from decaying plant matter.

Fungi play a major role in helping plants direct nutrients to their root systems. In the Jarrah forest, the mycelium of many fungi attaches to the rootlets of plants and channels nutrients in the soil towards the plants' rootlets. In that way, trees and shrubs are able to obtain water and scarce nutrients from the soil. In exchange, fungi receive food in the form of sugars from the plant roots.

Fungi absorb water and nutrients for plants.

Woylie Diggings and Rainfall

In an environment like the Jarrah forest, where little rain falls for up to eight months of the year, it is important for plants to be able to use water as efficiently as possible. Woylie diggings help water penetrate through the soil to the root system of plants by breaking up the soil surface, which is often water-repellent.

Woylie diggings help water penetration.

The Heartleaf Poison

The Heartleaf Poison, *Gastrolobium bilobum*, a shrub from the pea family, grows into a thick understorey that provides a habitat where Woylies are safe from predators, such as eagles and foxes.

The Heartleaf Poison takes its name after its heart-shaped leaves and from the naturally occurring toxin 1080, which is present in the plant, as well as in several other native plants of the pea family.

The Heartleaf Poison plant contains the poison 1080.

The Woylie has a very high tolerance to 1080 and can eat leaves and seeds of Heartleaf Poison without being affected by the toxin. Foxes on the other hand are killed by a minute dose of 1080. Foxes may be killed by eating Woylies that have undigested Heartleaf Poison seeds or leaves in their stomach. Woylies may have a better chance of surviving in areas where Heartleaf Poison is common because foxes are likely to be scarcer there.

Woylies have a high tolerance to 1080, but foxes are killed if they eat it.

The Heartleaf Poison, as other plants of the pea family, is also known to fix nitrogen in the soil. Nitrogen is an important source of food for plants. It is also a major constituent of fertilisers. Thus the presence of Heartleaf Poison may benefit other plant species in the Jarrah forest, including taller trees that form the forest canopy.

The Heartleaf Poison is nitrogen-fixing and improves the soil.

Human Impacts

The Role of Fire

Heartleaf Poison is a short-lived species for which seed germination is stimulated by fire. Thus regular burning assists with regeneration.

Fire helps the germination of Heartleaf Poison.

After a fire has occurred, Woylies appear to seek recently-burnt areas to feed on fungi and at the same time they scatter their dung pellets containing fungal spores on the bare ground. This probably helps underground fungi to recolonise the burnt area. Scientists have shown that underground fungi

grow better within the root system of seedlings in the presence of Woylie dung, and that Heartleaf Poison seedlings grow faster in the presence of the fungi. Thus it appears that Woylies may improve regeneration of Heartleaf Poison thickets.

Woylies helps both the fungi and Heartleaf Poison to grow well.

There are other beneficial effects of fire in the Jarrah forest ecosystem:

Fire has some beneficial effects in the jarrah forest.

- fire stimulates the growth of some fungi, which provide an additional food source for the Woylie and help trees and shrubs to channel nutrients to their root system;
- fire, by transforming plant matter into ash, helps release minerals into the soil, such as calcium and phosphorus;
- fire promotes the germination of many native species and stimulates the regeneration of Heartleaf Poison, which is the Woylie's favourite habitat.

However, fire also has adverse effects:

Fire also produces problems in the forest ecosystem.

- fire leads to an increased predation on Woylies in the months that follow fire by removing the undergrowth that provides shelter and protection from foxes and native predators;
- fire consumes the organic matter contained in the litter and in the soil several centimetres down into the ground (in the case of hot fires), thus removing precious nutrients required by plants and interrupting natural decomposition by bacteria and fungi in the forest litter;
- fire kills some of the fungi that grow under the soil surface by heating the upper ground layer;
- frequent fires may speed up the spread of dieback by increasing the amount of infected soil movement, due to erosion, when it rains;
- when fires are frequently lit (for example, less than 5 year intervals) to reduce the risk of wildfires, there may not be enough time between the fires for plants to produce viable seed, i.e. seeds that can successfully germinate and produce a new plant. Ultimately, there may not be enough seed in the soil and some plant species may become locally extinct.

Logging in the Jarrah Forest

Logging removes much of the vegetation cover in the Jarrah forest, as only isolated habitat trees and narrow forest corridors are left standing. Large-scale disturbances, such as logging, modify the habitat of Woylies and make them even more dependent on regular fox baiting for their survival. Furthermore, hot fires are lit after logging and these interrupt the continuing process of decomposition in the forest litter.

There are many other animals that are part of the Jarrah forest web of life. Some, such as the Ringtail Possum, the Brushtail Phascogale, and the Baudin's and Red-tailed Black-Cockatoos, require hollows for shelter and to breed. As thousands of hectares of Jarrah forest are logged every year, old trees which provided hollows for many native species disappear. It usually takes at least 130 years for a tree to develop hollows suitable for wildlife, and logging is likely to have an impact for very many years on the hollow-nesting species that live in the Jarrah forest.

Trees need many, many years to develop nesting site hollows for native animals.

The Woylie Back from the Brink

A recovery plan for the Woylie has been developed involving an intensive fox baiting program and the reintroduction of Woylies to places from which they had disappeared. These actions have resulted in a rapid increase in Woylies in some parts of the South-west forests and the Wheatbelt. Woylies have recently been reintroduced to the Shark Bay area.

To help increase Woylie numbers even further, it is necessary for scientists to understand more about the Woylie's habitat requirements and its interactions with other plants and other animals in the forest.

The Woylie recovery program has involved fox baiting.

List of Plants and Animals

Common Name	Scientific Name	Organism Type
Plants		
Jarrah	*Eucalyptus marginata*	Tree
Marri or Redgum	*Corymbia calophylla*, formerly *Eucalyptus calophylla*	Tree
Heartleaf Poison	*Gastrolobium bilobum*	Shrub
Mammal		
Woylie, or Brush-tailed Bettong	*Bettongia penicillata*	Marsupial
Quenda, or Southern Brown Bandicoot	*Isoodon obesulus fusciventer*	Marsupial
Quokka	*Setonix brachyurus*	Marsupial
Ringtail Possum	*Pseudocheirus occidentalis*	Marsupial
Brush-tailed Phascogale	*Phascogale tapoatafa tapoatafa*	Marsupial
Bush Rat	*Rattus fuscipes*	Native rodent
European Fox	*Vulpes vulpes*	Introduced predator
Birds		
Long-billed White-tailed Black-Cockatoo or Baudin's Cockatoo	*Calyptorhynchus baudinii*	
Forest Red-tailed Black-Cockatoo	*Calyptorhynchus banksii naso*	
Insects		
Dung beetle	*Onthophagus ferox, O. rupicra, Thyregis* spp.	Scarab beetle
Fungi		
Truffle-like fungi	*Mesophellia* spp. and many other species	Underground fungi

Dieback Disease

Dieback (*Phytophthora cinnamomi*) is an introduced fungal disease that infects the root system of many plants in the Jarrah forest. Dieback has had a damaging impact on the South-west's native flora. There is no known cure for dieback, but the injection or spraying of the chemical phosphonic acid has been shown to boost resistance of plants to the disease.

Dieback is an introduced fungal disease.

Dieback is a major threat to plants in the Jarrah forest, attacking and often killing many plants, such as members of the banksia and eucalyptus families (including Jarrah). The disappearance of Woylies from much of the Jarrah forest may make plants more susceptible to dieback as the balance between underground fungi, plants and mammals is disrupted.

Dieback affects many plant species, often killing plants over large areas.

A Fragile Ecosystem Under Pressure

The complex relationships between the various components of the Jarrah forest are not well understood, and the long-term impact of many human activities may only become clear when it is too late to correct the damage inflicted on this ecosystem.

The impact of humans is not fully understood.

Large-scale disturbances to the forest are likely to have a major impact on the Jarrah forest web of life. Wildfire, insect attack, plant disease (e.g. dieback) and human activities, such as clearing for agriculture, logging, mining and prescribed burning, have the potential to seriously disrupt the forest web of life and the balance between marsupials, fungi and plant species.

Many factors disrupt the delicate forest web of life.

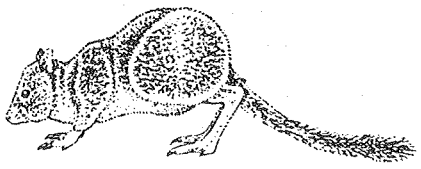
Scientists do not exactly know why Woylies (and many other small marsupials) have disappeared from most of Australia. Reasons probably include overgrazing by rabbits and domestic stock (sheep and cattle), broad-scale clearing, fox and cat predation, logging and changed fire regimes after the displacement of Aboriginal people.

Many factors have caused the disappearance of the Woylie from most of its original range.

We can imagine what the consequences of the disappearance of Woylies from much of the Jarrah forest may be. For example, these consequences may include:

- no Woylie dung pellets to disperse the spores of the underground fungi on which Woylies feed;
- fewer fungi to channel nutrients to the tree roots, thus the trees may not get enough food and may become more vulnerable to fire damage, insect attack, disease or drought;
- rainfall does not reach the tree roots because the soil surface is not broken up by Woylie diggings;
- dung beetles may disappear from the forest if they cannot find Woylie dung pellets;
- Heartleaf Poison may find it more difficult to regenerate after fire.

Many other organisms are likely to be affected if Woylies disappear from the forest.



What We Can Do

Conservation of fores ecosystems contrib utes to restoring th forest web of life.

Protecting forest ecosystems from large-scale disturbances may be the best thing we can do to restore the delicate balance of the web of life in the Jarrah forest. As a result of fox control, for example, Woylies escape predation, and Woylie diggings have been seen again in some parts of the South-west.

By working to restore the intricate web of life in the Jarrah forest, we can help Woylies, dung beetles, underground fungi and Jarrah trees to re-establish their connections.

Suggested Activities

Jarrah Forest Jigsaw

The aim is to create a pictorial representation of the way that the various plants, animals and insects "fit" into the Jarrah Forest.

Teacher makes up a "jigsaw" using cardboard or card. Pieces need to be large enough for students to write on. (Ideally, the jigsaw would form the shape of a Woylie).

Each piece of the jigsaw is to have the title of one area of the Jarrah forest for the students to research using the notes from the biodiversity package and any supplemental information. The "List of Plants and Animals" on page B7 would provide these areas.

Each pair of students is given one jigsaw piece. They write key information on their jigsaw piece.

When agreed time-frame for research has elapsed, each pair of students brings their piece to the jigsaw and explains it to the rest of the class. Students should start piecing together the jigsaw.

Once the jigsaw is completed, students can observe the interactions between the different parts of it. To highlight these interactions, connecting lines are drawn between all parts of the jigsaw.

Note that the jigsaw is only complete when **all** pieces are in place and that, when you only focus on one piece, you cannot see the whole picture.

Once all the lines have been drawn, a student is then asked to remove one piece from the jigsaw. Students to observe the effect of the removal of one piece from the jigsaw in the context of the plants and animals affected.

Students to then write, in their own words, what they understand from the jigsaw about the interactions in the Jarrah Forest. Allow several students time to share their writing and discuss what they have learnt.

The jigsaw would ideally be displayed prominently in the classroom and act as the focus for further discussion on the human impacts on the Jarrah Forrest.

Selling the Woylie

Teacher sets scenario: The ingenious humans have decided that the Woylie is a very cute creature but is now past its 'use by' date. In order to ensure that they have not 'lost' anything by allowing the Woylie production to continue, the humans have decided to sell all their Woylie stocks to a prospective buyer 'Extinction International'.

The purpose of this game is for the forest plants and animals (represented by various students) to convince the humans that they cannot afford to sell-out the Woylie in Western Australia.

Each student in the class is to decide which aspect of the Jarrah forest they would like to examine more closely e.g. Woylie, Heartleaf Poison, Fungi, Dung beetle, trees.

The students to form groups based on their choices and discuss the features of their chosen animal or plant and the effect of losing the Woylie on that animal/plant.

Each group must decide on ways to 'sell' or promote their own importance to the ecosystem and to argue that the 'sale' of the Woylie would affect far more than other Woylies. To support their sales pitch, the groups should produce a web of life diagram and any other visual support material they can. The groups then choose a person to present all their arguments to the "humans" (teacher or selected peer group).

Application to the Student Outcome Statements

Society and Environment - Place and Space (Care of Places); Investigation, Communication and Participation (Processing and Interpreting Information)

Science - Life and Living

English - Speaking and Listening (Use of Texts, Processes and Strategies); Reading (Use of Texts, Processes and Strategies); Writing (Contextual Understanding, Processes and Strategies)

Arts - Communicating Arts Ideas

Extension Activities for Students

Science, and Society and Environment

1. What is a symbiotic relationship? Give three examples of symbiotic relationships in the Jarrah forest web of life: between an animal and a plant, a plant and a fungus, and an animal and a fungus. Draw a diagram of a web of life in the Jarrah forest.
2. Form groups of seven students, with each student representing one of the following: Woylie, dung beetle, Jarrah tree, Heartleaf Poison shrub, truffle fungus, fox and human. Describe the relationships between all of these components of the Jarrah forest web of life and write them down. Alternatively, you might like to draw a sketch of the Jarrah forest, using arrows to link the animals, plants and fungi which are interdependent. What would happen to the relationships between plants, animals and fungi if a bushfire occurred? Write or re-draw your thoughts.
3. If the Woylie was to disappear, predict what could happen:
   a) to the fungi;
   b) to the dung beetle;
   c) to the trees and shrubs in the Jarrah forest.
4. Name two actions which have helped increase Woylie numbers. How has each helped the Woylie? Knowing that the Woylie's survival depends on the diversity of life in the Jarrah forest, list and explain two other actions that may help conserve biodiversity in the forest.

5. Imagine that you are in charge of managing a large nature reserve in the Jarrah forest. What actions would you take to make sure all the different parts of this web of life are preserved? (Think of all the possible threats or impacts on this environment.)
6. Visit the following websites on the Internet:
   - http://www.biodiversity.environment.gov.au/plants/threaten/index.htm
   - http://www.nccnsw.org.au/member/tsn

   Compile a summary of facts on threatened mammals:
   - what species are threatened?
   - what are the threats to these species?
   - what is being done to save them?
   - what is being done to protect biodiversity?

The Arts and English

Art: create your own art work based on the relationships between Woylies, underground fungi, dung beetles, the Jarrah forest and its web of life, inspired from the information presented above. Art work could include drawings, paintings, sculpture, pottery, photographs or a class mural.

Drama: write and act out a play based on the life story of the Woylie. Characterise the actors (i.e. plants, fungi, animals, humans), imagine how the story line could develop, introduce elements of conflict and decide on an ending.

Field Studies

1. Locate fungi around the school grounds or in a nearby bushland area. (Winter time is best). Without removing the fungus from its site, sketch and carefully describe each specimen, including the shape, size, colour, smell and any other characteristics.
2. Make a spore print by applying a white sheet of paper under the mushroom cap (this only applies to fungi with a cap). Allow up to one hour or more for the spores to be deposited on the paper. Store the paper with the spores for future reference with an appropriate label describing the fungus, its collection site and date of collection.
3. Examine spores under the microscope: place some of the spores scraped from the spore print in a drop of water between two glass slides and observe them using a microscope (100x to 400x). Note the colour and shape of the spores next to the description of the fungus.
4. How many different types of fungi have you found? What are the main differences between them?

For more details about collecting and identifying fungi, refer to the two field guides (see section 'Further Reading' below):

'A Field Guide to the Larger Fungi of the Darling Scarp and South-west of Western Australia', by K. Griffiths.

'Fungi of Southern Australia', by N. Bougher and K. Syme.

Note that fungi, like plants, are fully protected and cannot be collected without a permit.

Further Reading

On Fungi

Bougher, N. L. and Syme, K. (1998). 'Fungi of Southern Australia'. University of Western Australia Press, Nedlands.

Griffiths, K (1985). 'A Field Guide to the Larger Fungi of the Darling Scarp and South-west of Western Australia'. Published by K. Griffiths, (08) 9295 4212.

Hilton, R. N. (1988). 'Larger Fungi of the Jarrah Forest'. Conservation Council of Western Australia, Perth.

On the Woylie

Bamford, M. (1997). 'Bettongs Reap the Fruit of their Labour'. The West Australian, Earth 2000, 14 July 1997.

Christensen, P. E. S. (1995). 'The Brush-tailed Bettong'. In: Strahan, R. (Ed.). 'The Australian Museum Complete Book of Australian Mammals'. pp. 184–85. Cornstalk Publishing, Collins/Angus Robertson.

Johnson, B. and Thomson, C. (undated). 'Mammals of the South-west'. Department of Conservation and Land Management, Como.

Start, T., Burbidge, A. and Armstrong, D. (1995). 'Woylie Recovery Plan'. Wildlife Management Program No. 16. Department of Conservation and Land Management, Como.

Contacts

CSIRO, Division of Forestry and Forest Products, C/- Dr Neale Bougher, Tel. (08) 9333 6673.

Curtin University, School of Environmental Biology, C/- Assoc. Prof. Byron Lamont, Tel. (08) 9266 7784.

Department of Conservation and Land Management, Wildlife Research Centre, C/- Dr Tony Start, Tel. (08) 9405 5100.

Environment Australia, Community Information Unit, Canberra, Tel. (FREECALL) 1800 803 772.

Katrina Syme, mycologist, Denmark (Western Australia), Tel. (08) 9848 1293.

Threatened Species Network, Tel. (08) 9387 6444.

WA Gould League, Herdsman Lake Wildlife Centre, Tel. (08) 9387 6079.

Western Australian Herbarium, Tel. (08) 9334 0500.

Glossary

The definitions relating to fungi have been derived from the book 'Fungi of Southern Australia', by N. Bougher and K. Syme.

Ecosystem

Term used to describe a specific environment and all the interconnections between its different parts, including animals, plants and micro-organisms.

Endangered

Species which is in danger of becoming extinct, or likely to become in danger of extinction if its decline continues.

Fungus (plural fungi)
Unlike plants, which derive their energy from the sun to produce their own food, fungi absorb food through filaments called mycelium (see below).

Germination
Process by which a seed or spore produces a new plant or fungus.

Habitat
Part of an ecosystem used by a species for its breeding, feeding and resting purposes.

Marsupials
Type of mammals where the young are born after a short gestation and continue their development in the mother's pouch, e.g. kangaroo, Woylie.

Mushroom
A type of fungus with a fruiting body above ground.

Mycelium
Main body of the fungus that looks like white or coloured filaments, frequently underground, often hard to see with the naked eye, in the vegetation litter or in rotting wood.

Prescribed burning
A burning operation in bushland deliberately lit and controlled by humans, usually as part of a land management program; for example, to reduce the chance of uncontrollable bushfires or to control weeds.

Reintroduction
Release by humans of an animal or plant species into an area where it used to occur, but is no longer present.

Spore
Microscopic reproductive cell that produces a new fungus or plant (such as a fern and moss) by germination.

Symbiosis
Beneficial relationship between two or more organisms.

Threatened
A species or community that is vulnerable, endangered or presumed extinct.

Truffle
Fungus with an underground fruiting body, often round in shape like the much sought after European 'truffle'; these fungi are the Woylie's favourite food.

Case Study 2
Mistletoe, Mistletoebirds, Butterflies and Ants

What is Biodiversity?

Biodiversity represents the sum of all living organisms, such as plants, animals and micro-organisms, their genetic variations and their interconnections within complex ecosystems.

Biodiversity exists everywhere: in forests, mountains, deserts, lakes, rivers and oceans. It is present in cities, houses and backyards, on farms and in any human modified environment, as well as around our bodies, on our skin and in our internal organs.

Biodiversity is the variety of life forms which exist on the Earth.

Biodiversity includes not only the plants and animals that we see around us (including ourselves), but also the myriad of microscopic organisms that inhabit our environment, such as fungi, algae, bacteria and viruses.

Most of the Earth's biodiversity consists of a large number of invertebrates, fungi, bacteria and non-flowering plants. Vertebrate animals and flowering plants represent only a small fraction of the total biodiversity, probably less than 1% in number of all species on Earth.

The Mistletoe Web of Life

Australian mistletoes represent a microcosm of biological diversity. There is a diverse and remarkable community of birds, butterflies and ants that live around mistletoes and their plant hosts. This story is about the South-west mistletoes, their host trees, and their association with Mistletoebirds, brightly coloured butterflies, tiny black ants, honeyeaters and brushtail possums.

A large number of organisms are associated with mistletoe plants.

The mistletoe story illustrates the diversity of different plants, animals and other life forms that have developed a connection with the mistletoe, and it explains their relationships and dependencies.

The Plants

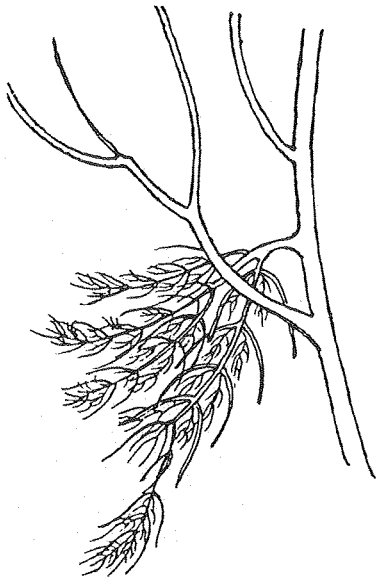
The Mistletoes of the South-west and Their Host Plants

Mistletoes are parasitic plants that grow on the branches of various trees and shrubs, including eucalypts, wattles, teatrees and sheoaks.

Mistletoes get their food and water directly from their host plant. This relationship is one-sided, as the mistletoe takes its food from the host, but the host does not receive any direct benefit in exchange.

Mistletoes are parasites - they get their food from another plant.

Host - organism which supports the parasite.



(Right) Figure 1. Mistletoe grows on the branches of other trees.

Figure 2. The Mistletoe Web of Life.

Depending on the size and vigour of the mistletoe and its host, the host plant can be weakened and sometimes dies, but generally the parasite coexists with its host without killing it.

Most parasites do not kill their host.

Australian mistletoes (scientific genus names *Amyema* and *Lysiana*) belong to the family Loranthaceae. The family also includes the magnificent Christmas Tree, *Nuytsia floribunda*, the largest parasitic plant in the world, which is renowned for its bright orange flowering around Christmas time. The European mistletoe belongs to a different family (Viscaceae) and does not occur in Australia.

Australia has the largest plant parasite in the world.

This story involves four species of mistletoe that occur in the South-west of Western Australia (see Table 1). Some of them have adapted to the suburban backyards and parks of Perth and country towns, and grow well on species of wattles introduced from Eastern Australia.

The Birds

The Mistletoebird and the Germination of Mistletoe Seeds

The Mistletoebird is a handsome bird found throughout the mainland of Australia wherever there is mistletoe. The male is glossy black above with a scarlet-red throat and chest. The female is brownish-grey above with whitish underparts.

The mistletoebird is found throughout Australia.

There is life after death

Even when the host plant dies, there is some benefit for the other species that live in this environment. Dead eucalypts are an important part of the web of life. They are used by insects and other invertebrates, which feed on the dead or decaying wood, and by parrots and cockatoos, which nest in their hollows. When a tree or a shrub dies, seedlings of other plants take advantage of the sunlight reaching the ground through the gap created in the vegetation canopy.

Even dead plants are beneficial in ecosystems.

Parasite Mistletoe species	Distribution	Host Host species	Where found
Amyema miquelii	Across Australia	Eucalypts, such as Marri and Wandoo	Jarrah forest and eucalyptus woodland in the South-west.
Amyema preissii	Across Australia Queensland Silver Wattle Black Wattle	Jam tree and other native wattles	South-west inland from coast. Both planted as ornamental (Black Wattle now a woody weed in the jarrah forest).
Amyema linophyllum	Across Australia	Mainly Swamp Sheoak	Coastal areas from Mandurah to Kalbarri and inland regions
Amyema melaleucae	WA, also SA	Coast Teatree Sandalwood Quandong	Coastal areas around Perth and Albany. Rottnest, Garden Island, SW of WA.

Table 1. The four common mistletoes in the South-West.

The Mistletoebird feeds mainly on the fruit of the mistletoe (other fruits and insects are eaten at times). For this reason a Mistletoebird is never very far from a mistletoe plant and the best way to find this species is to locate an area of bush where mistletoe is abundant. After ripening, mistletoe berries stay attached to the host plant and provide a ready food supply for Mistletoebirds all year round.

The mistletoebird feeds on the fruit of the mistletoe.

The bird squeezes the fruit with its beak to extract the sweet flesh of the berry which contains the seed. The berry passes through the bird in as little as 30 minutes and comes out in the bird's dropping with the seed still coated in the sticky flesh of the berry. To detach the sticky dropping, the bird turns sideways when defecating and rubs it against a branch, so that its dropping sticks to the branch of the tree where the bird is sitting. Thus the seed is in an ideal position to germinate and produce another mistletoe plant.

The digested fruit, which passes through the bird, sticks to branches where it can germinate. Unlike other birds, the mistletoebird stands sideways on the branch.

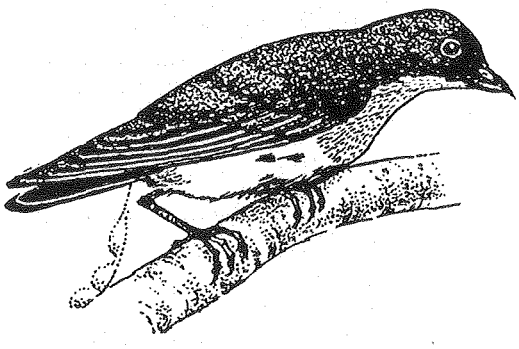


Figure 2. The mistletoebird stands sideways on a branch and deposits the sticky seed onto it.

The Mistletoebird

Aboriginal name: Moo-ne-je-tang.

Scientific name: *Dicaeum hirundinaceum*.

Family: Dicaeidae or Flowerpeckers (the Mistletoebird is the only member of this family in Australia). Flower-peckers are found throughout much of tropical Asia.

Size: 10–11 cm.

Conservation status: Common throughout the mainland of Australia.

Honeyeaters, such the Spiny-cheeked Honeyeater, also eat mistletoe berries and play an important role in spreading mistletoe seeds.

Honeyeaters

Honeyeaters are a family of birds (called Meliphagidae, meaning 'nectar eaters') which is particularly diverse in Australia where 67 species are found. They have a brush-tipped tongue specially designed to collect the rich nectar that is produced by many Australian plants.

The familiar green and red Mangle's Kangaroo Paw, *Anigozanthos manglesii*, the State's floral emblem which is common in bushland around Perth, is visited by several species of honeyeaters and relies on the birds for its pollination.

Honeyeaters and Mistletoe Pollination

Mistletoe flowers are bright red and attract honeyeaters. When a honeyeater feeds on the nectar inside a flower, its head lightly brushes the stamens of the flower and pollen is deposited on its feathers. The pollen is then taken to another flower by the bird and fertilises that flower.

Honeyeaters transfer pollen from one flower to another.

South-west mistletoes flower in summer, at a time when very few plant species are in bloom. Therefore, attraction is strong for honeyeaters to feed on mistletoe and mistletoe pollination is more likely. The nectar provided by the mistletoe to honeyeaters at this time of the year is likely to be an important source of food for the birds.

During summer, mistletoes provide nectar for honeyeaters.

Mammals: the Brushtail Possum

Brushtail Possums are known to be fond of mistletoe and, along with caterpillars, probably help keep mistletoe growth in check and ease the parasite's pressure on the host plant.

However, in many places brushtail possums have become quite rare (they have almost disappeared from the Wheatbelt).

Brushtail possums eat mistletoes and help control its growth and spread.

Butterflies and Ants

The Amaryllis Azure and its Ant Carers

The Amaryllis Azure is one of the largest and most beautifully coloured butterflies in the South-west. It has a wingspan of 3.5 cm and iridescent blue wings. But, despite its bright colour, this Azure is difficult to spot because it flies high among the tree tops where mistletoe grows. The best time of the year to spot the Amaryllis Azure is on a warm November or December day around trees where mistletoe grows. Butterflies are diurnal; that is, they are active during daylight hours.

Azure means blue. The Amaryllis Azure caterpillar feeds on mistletoe leaves.

The Amaryllis Azure has developed the most extraordinary association with little black ants of the genus *Papyrius* (formerly called *Iridomyrmex*). The butterfly lays its eggs on a mistletoe which grows on a tree that has been colonised by the ant. As soon as the eggs hatch, the ants take charge of the young butterfly larvae. The ants provide shelter to the newly-hatched caterpillars in their nest at the base of the tree or under the bark. The ants care for the caterpillars by shepherding them at the beginning of the night to a clump of mistletoe to feed, and by leading them back to their shelter before dawn. If there is danger at night, the ants will guide the caterpillar back to safety at the base of the tree.

Papyrius ants protect the butterfly caterpillar as it grows.

This relationship between the ants and the caterpillars is mutually beneficial. The ants provide the caterpillars with protection from parasitic wasps that lay their eggs inside the caterpillars. The nocturnal habits of the caterpillars fostered by the ants also protect the caterpillars from predation by birds that are active mainly during the day. In exchange, the caterpillars provide the ants with a nutritious sugary substance that they produce from glands located on their back.

Both ants and caterpillars benefit from their relationship.

The ants care for the caterpillars up until the time when they prepare to become pupae and turn into butterflies. Amaryllis Azure caterpillars are always found where these little black ants are present on a tree on which mistletoe grows.

Amaryllis Azure caterpillars are always found with the small black Papyrius ants

The Azure and Other Butterflies

Most of the 12 species of Azure butterflies known in Australia are associated with mistletoe. All of them are tended as caterpillars by *Papyrius* and *Camponotus* ants. Azure butterflies belong to the family Lycaenidae, and are called 'blues' because the upper sides of the wings are often iridescent blue. Four Azures are found in the South-west of Western Australia, as shown in the table below.

Caterpillars of all species of Azure butterflies are tended by ants.

Common name	Scientific name	Where found
Amaryllis Azure	*Ogyris amaryllis*	Across the South-west and throughout Australia.
Large Brown Azure	*Ogyris idmo*	Across the South-west, also Eastern Australia.
Silky Azure	*Ogyris oroetes*	Across the whole of Australia.
Western Dark Azure	*Ogyris otanes*	South Coast mainly, also Eastern Australia.

Table 2. The Azures of the South-west of Western Australia.

The caterpillars of other 'blues' are also tended by ants, but feed on plants other than mistletoe, mainly native peas and wattles. The caterpillar of the Western Jewel cannot survive without its ant carers. It cannot be reared outside the ant nest. A description of some of the caterpillar-ant relationships is found in Table 3. The caterpillar of the Wood White (*Delias aganippe*), a striking black and white butterfly (but not a 'blue'), also feeds on mistletoe. It is common in the South-west, mostly away from the coast. It does not, however, have a complimentary relationship with the Papyrius ant.

Some butterfly species cannot survive without their ant protectors.

Insects, the Hidden Biodiversity

Insects form a major component of biodiversity, although they are poorly known. Invertebrates represent 98 to 99% of the Earth's animal diversity. Insects play major roles in nature's processes, such as pollination, control of plant growth, dispersal of seeds, decomposition of plant and animal matter, and the processing of nature's waste products. They are an important source of food for many animals.

Insects affect almost all other species on Earth and have important roles to play in nature.

Common name	Scientific name	Found where	Tended by ants
Icilius Blue	*Jalmenus icilius*	Across the SW	*Papyrius*
Inous Blue	*Jalmenus inous*	Across the SW	*Papyrius*
Western Jewel	*Hypochrysops halyaetus*	Perth and coastal plain	*Crematogaster perthensis*
Fiery Jewel	*Hypochrysops ignitus*	South Coast	*Papyrius nitidus* and allied species
Fringed Blue	*Neolucia agricola*	Across the SW	Yes (species unknown)

Table 3. Blues of the South-west of Western Australia and their ant carers.

Insects have complex, essential relationships with the more visible parts of the world around us: mammals, birds, reptiles, frogs, plants. Without insects, there would not be the rich diverse web of life which exists today.

Biodiversity and Ants

Australia is renowned for its extremely diverse ant communities. There may be as many as 4000 species of ants in Australia, and up to 150 species of ants can be found at a single site. Ants play significant roles in ecosystems: they help disperse seeds of many native plants, they recycle and redistribute nutrients, and they aerate soils. Ants also have associations with insects other than caterpillars: they are known to 'farm' colonies of mealybugs and scale insects which they exploit for the honeydew these insects produce.

There are thousands of species of ants in Australia, each having significant roles in ecosystems.

Ants and plants have sometimes established mutually beneficial relationships. This is the case for instance with some species of wattles which have seeds borne on a fleshy stalk called an 'aril' that is sought by ants as a food. The ants take the seeds and bury them in their nest where these can germinate after the aril, but not the seeds, has been consumed by them. In the Jarrah forest, wattles are believed to slow down the spread of the dieback disease through the forest; thus ants could be contributing indirectly to the control of the disease.

Ants help in the germination of some seeds, such as those of wattle trees.

Biodiversity and Butterflies

Butterflies and moths are one of the most diverse groups of insects on Earth. There are 18,000 species of butterflies and moths worldwide. They belong to the order Lepidoptera, the second largest insect group after the beetles. There are over 2,000 species in Australia alone, although only 400 or so are butterflies. Surprisingly, the South-west has only just over 50 species of butterflies, a low number given the large number of nectar-producing plants in the South-west.

Only a relatively small number of butterfly species exist in the South-west.

The Dinosaur Ant, a 'living fossil'

The Dinosaur Ant, *Nothomyrmecia macrops*, is a primitive species of ant very similar to ant fossils dating back 70 million years. Discovered in Balladonia, east of Esperance in 1931, it has not been seen since in Western Australia, but was rediscovered in 1977 in South Australia and is only known at a few sites.

Living fossil: an organism which existed many millions of years ago and still lives today.

Butterflies and their caterpillars play an important ecological role. Caterpillars, like other herbivores, keep plant growth in check. They also are an abundant source of food for birds and insects. Many butterflies feed on the nectar produced by flowers and contribute to plant pollination by carrying pollen from flower to flower.

Caterpillars regulate plant growth but are also eaten by birds and other animals.

A Fragile Balance

Complex relationships have evolved around the mistletoe between plants, birds and insects. Some of these relationships are 'obligate'; that is, one species cannot exist without the other. Other relationships are 'facultative', meaning that while one species has an association with another species, it can also live without that other species. Other dependencies are of a parasitic type, where one species derives its food from the bodies of another species, usually to the disadvantage of the latter.

Obligate: cannot live without each other. Facultative: each species in a relationship can survive without the other.

The relationship between the Mistletoebird and mistletoes appears to be one of mutual dependency. Neither species would be able to exist without the other.

The connection between the Amaryllis Azure and the black ants is one of mutual benefit, but not of exclusive dependency: the ants are able to survive without the caterpillar, but seem to actively seek the caterpillars and protect them. The caterpillar's survival is enhanced by the ants. In exchange, the ants feed on the secretion produced by the caterpillars.

The Amaryllis Azure butterfly and the black ant have mutually beneficial relationship.

The relationship between the mistletoe and its plant host is parasitic as the mistletoe takes its food from its host without giving anything in exchange. The following table summarises the variety of the relationships in the web of life that exists around the mistletoe.

The complex web of life that exists around the mistletoe is fragile. With the clearing of much of the native vegetation in the Perth area, many butterflies, including some of the blues, have become quite rare or have disappeared. Native ants, such the *Papyrius* ants, have been replaced by the

Species A	Species B	Interaction	Type of relationship	Level of dependency
Mistletoe	Tree host	Plant-Plant	Parasitic	Obligate for the mistletoe
Wasp	Amaryllis Azure	Insect-Insect	Parasitic	Obligate for the wasp
Mistletoe	Mistletoebird, honeyeaters	Plant-Bird (seed dispersal)	Mutually beneficial (symbiotic)	Essential, but possibly not obligate
Mistletoe	Honeyeater	Plant-Bird (pollination)	Mutually beneficial (symbiotic)	Important, but probably not essential for the mistletoe and for the bird
Amaryllis Azure	*Papyrius* ants	Insect-Insect	Mutually beneficial (symbiotic)	Obligate for the caterpillar, facultative for the ants
Amaryllis Azure	Mistletoe	Insect-Plant	Predation by herbivore	Obligate for the butterfly
Brushtail Possum	Mistletoe	Mammal-Plant	Predation by herbivore	Facultative for the Possum

Table 4. The mistletoe and its web of life.

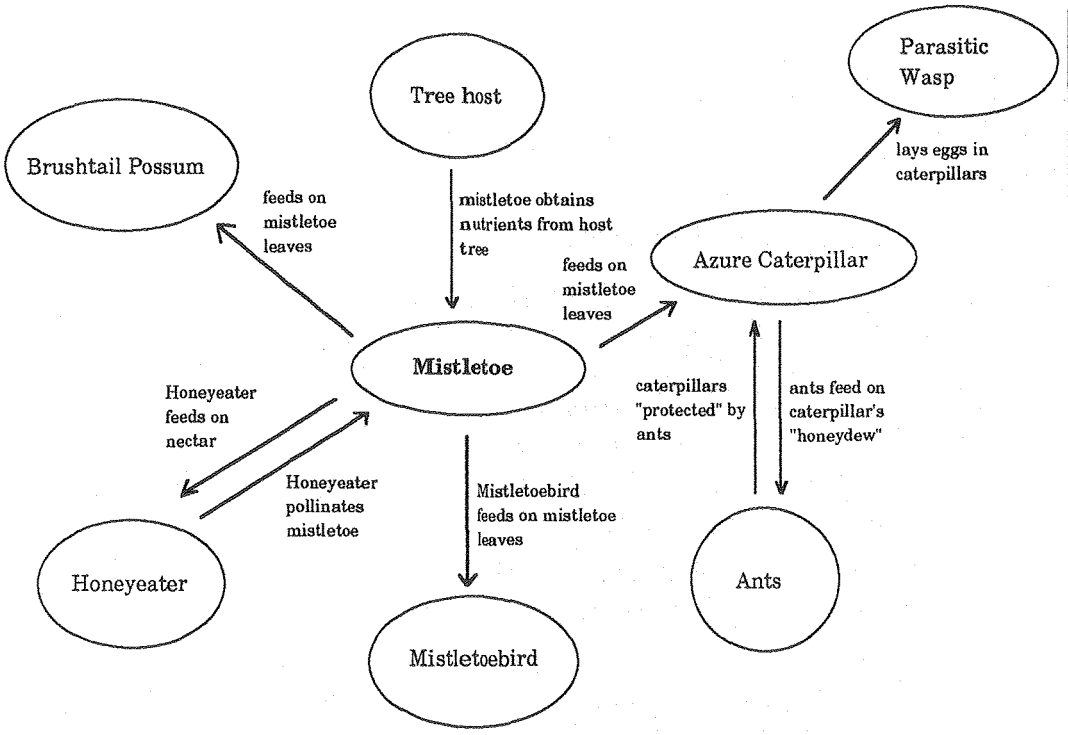


Figure 2. The mistleltoe, it's relationships and the web of lfe.

Coastal Brown Ant which thrives around suburban homes.

In the Wheatbelt where only small remnants of bush remain, mistletoe has sometimes taken over and threatens to kill its host plants. The reasons for this are largely unknown, but it may be due to things like a reduction in natural vegetation (more mistletoe plants on less hosts) and trees which are stressed, dying or diseased, and thus become targets for the mistletoe.

Clearing vegetation results in a decrease in butterfly populations.

The decline in numbers of many species of honeyeaters in the Wheatbelt may also put the pollination of the mistletoe by these birds at risk. With reduced pollination by birds, mistletoes may become rarer and the Mistletoebird may not be able to find its favourite food. If mistletoes disappear in an area, the local population of honeyeaters may have to switch to another food source during the summertime; if no other food is available, the birds may have to leave the area and the population may ultimately become extinct.

Numbers of honeyeaters have also declined, reducing mistletoe pollination.

It seems contradictory that in some places mistletoes would become too abundant, and in other places be at risk of disappearing. This is a sign that our environment has become out of balance.

What We Can Do

The best thing we can do to conserve the mistletoe web of life is to preserve its environment. To do this, we can:

- conserve native bush, protect remnant vegetation from clearing, grazing, fire and weeds;
- replant a wide range of host species for mistletoe;
- conserve or replant corridors with plants that are hosts for mistletoes. In that way Mistletoebirds can find food while flying from one remnant of vegetation to another;
- avoid disturbing ant nests around trees which are hosts for mistletoe.

Suggested Activities

Colours in Nature

This activity will help students to recognise that colours are important in Nature, to appreciate the symbolic nature of certain colours, and to experiment with colour for making meaning.

Each student is given a sample of one of the colours mentioned in the case study. Students then team up with others who have different coloured cards to their own. The group which forms may have only one of each colour represented.

Groups brainstorm and decide which animal or plant in the case study is represented by each member's colour sample. Individuals then create the animal/plant they represent, having first decided as a group on the relative size of each, in order to make a group poster. This poster needs to show the relationships between these plants and animals.

Alternatively, utilise the colours to create a poster educating people about the need to protect biodiversity.

Mistletoes are a Must

Students are to make a current affairs television program that investigates the claims that Mistletoes are important. (For schools with limited or no access to audio-visual equipment, this could be in the form of a storyboard or written script.)

Sample Press Release Information:

The Western Australian Mistletoe representative body 'Mistletoes of W.A.' has announced that they are undervalued and are launching a 'Mistletoes are a Must' campaign to educate Western Australians about their importance to our environment.

A spokesperson for the group, Mavis Mistletoe has said that, with the loss of Mistletoes, many other creatures are affected and may disappear altogether.

Ms Mistletoe is concerned that unless Western Australian people recognise the role of the Mistletoes as part of our biodiversity, many parts of our ecosystem will be damaged with dire effects.

Suggested procedure:

Small groups of students are given the Press Release as a springboard to the activity as well as a copy of the Case Study information.

Each group should start by making a picture-gram of the mistletoe web of life.

Students should give each life form in the picture-gram a name and a 'position title' e.g. Wilbur Wasp - Parasite.

The project requires the student news teams to interview each character on the way the Mistletoe influences them.

Students will need to consider the presentation of the information in the context of what the main message of the story should be. (Consideration of bias and balanced presentation will be needed).

The completed current affairs programs should be viewed by peers for peer assessment of the effectiveness of the presentation and information.

Application to the Student Outcome Statements

Studies of Society and Environment - Natural and Social Systems; Investigation, Communication and Participation

English - Speaking and Listening; Reading; Writing

Science - Life and Living

Arts - Using Arts Skills, Techniques, Technologies and Processes; Communicating Arts Ideas

Extension Activities for Students

Science, and Society and Environment

1. Draw the web of life of the mistletoe on a large sheet of paper that illustrates the different connections between the mistletoe, its tree host, azure butterflies and caterpillars, ants and possums. Put a cross through one of the organisms and imagine what would happen if that organism disappeared from this web.
2. Find out what the following words mean and apply them to the different relationships in the mistletoe story: ecosystem, nocturnal, diurnal, symbiosis, parasitism, predation.
3. Find another organism which is a parasite and describe its relationships in any way you like (drawing, cartoon, tape recording, spoken word, ...).
4. Find pictures of the plants and animals mentioned in the mistletoe story. Use these to create a poster which tells us how they are all interconnected.
5. Visit the following website on the Internet:
   http://research.amnh.org/entomology/social_insects/
   Go to 'Images and Slide-shows' and 'Ants of Australia'. Find photos of the ant species *Iridomyrmex* (now called either *Iridomyrmex* or *Papyrius*) and *Camponotus* (both species tend the caterpillars of Azure butterflies).

The Arts and English

Art: Design an art piece based on the colours of the mistletoe flowers (bright red and green), the shimmering blue of the Amaryllis Azure, the golden yellow of the wattle flowers, and the glossy black and scarlet of the Mistletoebird.

Drama: Imagine a puppet show around the mistletoe web of life. Create puppets out of natural or recycled materials and build a stage as a background to the story.

Field Studies

1. Look for some ants around your school or in your nearest piece of bushland. Search on the ground, in the leaf litter, in shrubs and trees.
   - Collect a few ants of each species in a container or jar closed with a lid.
   - Make a note of the environment and the habitat where the ants are found: soil type (white, yellow or grey sand, clay, rocky, deep humus, etc.), vegetation (forest, woodland, shrubs, low cover), the type of plants that are there (eucalypts, wattles, ...), the presence of rocks or old logs, whether the area is in the shade or in open sunlight, etc.

- Draw a sketch of each type of ant on an A4 sheet of paper; place the scale next to the drawing and attach the notes you have taken on the habitat of each species.
- Compare your sketch to the photos on the website listed earlier and identify the species closest to it.

2. Create a native garden in your school specially designed to attract butterflies (see 'Bring Back the Butterflies: Butterfly Gardening for Western Australians' listed under "Further Reading" for a step-by-step guide). Seek help from the WA Insect Society or the Gould League if necessary (their contact phone number is provided in the Contacts section that follows).

Further Reading

Houston, F. T. (Ed). (1995). 'Bring Back the Butterflies: Butterfly Gardening for Western Australians'. WA Insect Study Society/Western Australian Museum, Perth.

Majer, J. (1984). 'Ant Experiments'. Science Teachers' Association of Western Australia, Perth.

Reader's Digest. (Ed). (1997). 'The Reader's Digest Complete Book of Australian Birds'. pp 550. Reader's Digest Publ., Sydney.

Simpson, K. and Day, N. (1996). 'Field Guide to the Birds of Australia'. Penguin Books, Australia.

Start, T. (1990/91). 'Much ado about Mistletoe'. Landscope 6 (2): 50-53.

Contacts

Birds Australia - WA Group, Tel. (08) 9383 7749.

Curtin University, School of Environmental Biology, c/- Prof. Jonathan Majer, Tel. (08) 9266 7368.

Environment Australia, Community Information Unit, Canberra, Tel. (FREECALL) 1800 803 772.

Science Teachers' Association of Western Australia, Tel. (08) 9244 1987.

Western Australian Herbarium, Tel. (08) 9334 0500.

WA Gould League, Herdsman Lake Wildlife Centre, Tel. (08) 9387 6079.

WA Insect Study Society, c/- Dr Terry Houston, Western Australian Museum, (08) 9427 2742.

Glossary

Defecation

Elimination of the waste products of digestion from the anus of an animal.

Ecosystem

Term used to describe a specific environment and all the interconnections between its different parts, including animals, plants and microorganisms.

Facultative relationship

Type of relationship between two organisms where one organism can exist without the other.

Germination
Process by which a seed produces a new plant.

Habitat
Part of an ecosystem used by a species for its breeding, feeding and resting purposes.

Herbivore
Animal (e.g. mammal, insect) that feeds on plants.

Invertebrate
Animal without a backbone.

Obligate relationship
Type of relationship between two organisms where one organism needs the other organism to exist.

Parasitic relationship
Type of relationship where one organism obtains its food from the body of another species (the host), without killing it directly.

Pollination
Transfer of pollen from the stamen, or male organ of the flower, to the pistil, or female organ so that fertilisation can take place and seed can be produced.

Symbiotic relationship, symbiosis
Beneficial relationship between two or more organisms, where each benefits.

Case Study 3
Honey Possums and Wildflowers

What is Biodiversity?

Biodiversity represents the sum of all living organisms, such as plants, animals and micro-organisms, their genetic variations and their interconnections within complex ecosystems.

Biodiversity exists everywhere: in forests, mountains, deserts, lakes, rivers and oceans. It is present in cities, houses and backyards, on farms and in any human modified environment, as well as around our bodies, on our skin and in our internal organs.

Biodiversity is the variety of life forms which exist on the Earth.

Biodiversity includes not only the plants and animals that we see around us (including ourselves), but also the myriad of microscopic organisms that inhabit our environment, such as fungi, algae, bacteria and viruses.

Most of the Earth's biodiversity consists of a large number of invertebrates, fungi, bacteria and non-flowering plants. Vertebrate animals and flowering plants represent only a small fraction of the total biodiversity, probably less than 1% in number of all species on Earth.

The Honey Possum's Web of Life

The Honey Possum's connection with its environment is complex and fascinating (see Figure 1). There is a two-way relationship between the Honey Possum and the plants which supply this small marsupial with food and shelter; the plants provide nutritious pollen and nectar to the Honey Possum and the marsupial transports pollen from flower to flower to complete the reproductive cycle of the plants.

Honey Possums feed on nectar and pollen

However, despite having been the object of detailed research since the 1970s, the Honey Possum's life cycle and relationship with its environment are far from being completely understood.

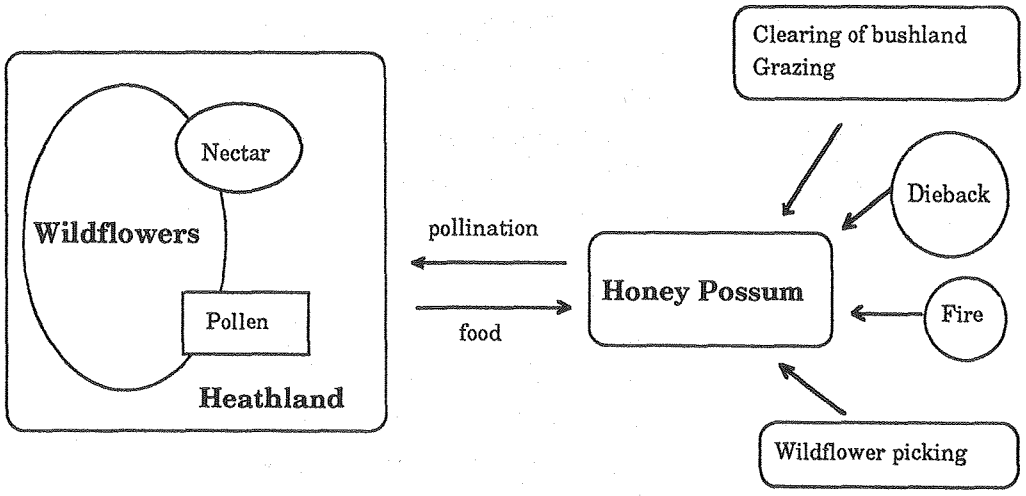


Figure 1. The relationship between the Honey Possum and its environment.

What do we Know About the Honey Possum?

The Honey Possum is a tiny, attractive marsupial which rarely comes into contact with humans. It is unique to the South-west of Western Australia, between Shark Bay and the south coast east of Esperance, as are most of the plants which provide it with food and shelter.

The Honey Possum is only found in the South-west.

Contrary to what its name may suggest, the Honey Possum is not a possum, or even closely related to possums (or any other existing group of marsupials for that matter). The Honey Possum is in fact the sole survivor of a marsupial group called Tarsipedidae.

The Honey Possum is a unique mammal, not closely related to other marsupials.

Diet

The Honey Possum's Dependence on Nectar and Pollen

The Honey Possum's diet is made up exclusively of nectar and pollen, which it collects with its long brush-tipped tongue which it inserts inside the flowers. Banksias and other plants of the banksia family are favoured, as well as native plants of the eucalypt family. Plants in both families have profuse blossoms made up of many flowers which provide an abundant food source for the species. The Honey Possum's specialised diet does not require teeth to be developed.

The Honey Possum's long tongue is specially adapted to feed on nectar.

The Honey Possum's survival depends on healthy, species-rich plant communities. One condition of the Honey Possum's existence is that there must always be at least one of the marsupial's food plant species in bloom through the year. As the Honey Possum requires nectar all year round, even brief shortages of food can drive a population to extinction. The small marsupial cannot easily switch to another food type, such as insects.

Because of their small size, Honey Possums must have food available at all times.

Scientists studied the main food plants used by a number of Honey Possums at one site on the South Coast. These food plants were (in order of decreasing importance): a *Beaufortia* bottlebrush, the Nodding Banksia, Albany Banksia, Oak-leaved Banksia, Bull Banksia, Coastal Jugflower, Slender Banksia, Gardner's Banksia, and Showy Dryandra. Different combinations of plants of the banksia and eucalypt families are visited in other parts of the Honey Possum's range.

Honey Possums feed on plants such as Banksia and Dryandra.

The Honey Possum and Plant Pollination

Nectar-bearing plants benefit from the Honey Possum's attentions. As the Honey Possum visits flower blossoms and inserts its pointy snout past the stamens, it collects pollen on its fur which it then transports to other flowers. Thus, the Honey Possum plays an important role as a pollinator, together with nectar-feeding birds such as New Holland Honeyeaters, Red and Little Wattlebirds and Purple-Crowned Lorikeets.

The Honey Possum transfers pollen from one flower to another.

A mutually beneficial relationship exists between plants and the Honey Possum - the Honey Possum finds an abundant source of food in the flower blossoms, and at the same time flowers are pollinated by the Honey Possum which helps the plant to reproduce.

Plants and the Honey Possum depend on each other.

The Honey Possum
Aboriginal name: Noolbenger.
Scientific name: *Tarsipes rostratus*.
Family: Tarsipedidae.
Size: 40–95 mm, plus tail 45–110 mm.
Weight: up to 12 g (males), 22 g (females).
Longevity: up to 1 year, rarely 2 years.
Conservation status: common, but with a limited and declining range; now extinct in most of the Central Wheatbelt.

It is easy to understand how the Honey Possum depends on nectar-producing plants. However, it is not clear whether the Honey Possum's role as pollinator is essential, and it is not known whether the disappearance of the Honey Possum from much of its range in the Wheatbelt has affected the reproduction of some plant species.

Distribution and Home Range

The Honey Possum is found west of an imaginary line joining Shark Bay to Esperance (see Figure 2). It has practically disappeared from the Wheatbelt due to a lack of remnant vegetation. In the Perth metropolitan area in recent years, the Honey Possum has been recorded only in Whiteman Park.

Honey Possums have a small living area, also called their home range (1300 m^2 for males, 700 m^2 for females). They usually remain in their home range all year round, but males move about within it more than do females.

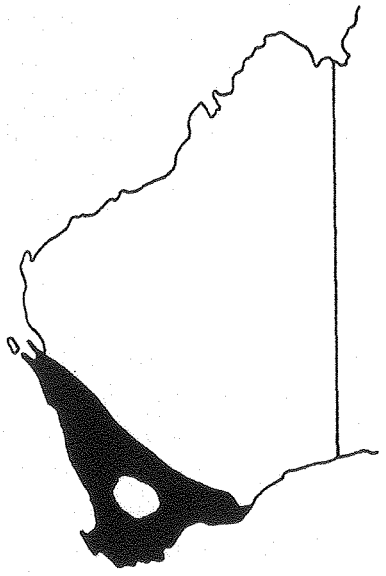


Figure 2. Distribution of the Honey Possum.

The Honey Possum moves within a small home range.

Habitat

Prime Honey Possum habitat seems to coincide with parts of the South-west where plants of the banksia family are most diverse: the Fitzgerald River/Albany area on the South Coast and the Eneabba/Mt Lesueur region in the northern sandplain.

These regions are as rich in flora as tropical rainforests: two square metres of heathland near Eneabba can contain up to 34 species of plants, one of the highest recorded number of plant species in such a small area.

Heathland can contain many different species of plants.

Reproduction

Females with young have been observed all year round, but the peaks of reproduction occur when nectar is most abundant. Females give birth to two to four young that live for several weeks in the mother's deep pouch before they venture out on their own.

What Happened to the Honey Possum?

Much of the Honey Possum habitat has been modified over the last 150 years. The Honey Possum has disappeared from most of the Central Wheatbelt, but is still widespread over the rest of its range. Food shortage from a lack of nectar-bearing flowers at a particular time of the year is a possible explanation for the decline of Honey Possum numbers, as well as frequent fires and clearing.

The Honey Possum has disappeared from the Central Wheat-belt.

Clearing and Grazing

In the Wheatbelt, much of the Honey Possum habitat has been cleared for agriculture. In many areas, all that is left of the Honey Possum's habitat

are patches of remnant vegetation which may not have the right variety of plant species to provide food for the small marsupial all year round. Grazing by farm animals (livestock) puts additional pressure on remnant vegetation by reducing the diversity of plants and suppressing natural regeneration.

Land clearing, mining and farming activities put populations of Honey Possums at risk.

Pressure to clear bushland for agriculture is continuing, particularly in the northern sandplains, the Scott River Plains (near Augusta) and the Esperance region. Mining for mineral sands is on the increase on the South Coast (Lake Jasper/D'Entrecasteaux National Park and the Scott River area), and the Lesueur National Park is still subject to a coal mining proposal. Honey Possums which inhabit these areas continue to be at risk.

Large bush fires and urban development are additional threats to Honey Possum habitat.

Dieback

Dieback (*Phytophthora* spp.) is an introduced fungal disease that infects the root system of many plants. Dieback has had a damaging impact on the South-west's native flora. It affects many species of the banksia and eucalypt families (among others), which include some of the favourite food plants for the Honey Possum. Dieback has severely reduced the populations of several species of banksias, including the Albany Banksia. There is no known cure for dieback, but the injection or spraying of the chemical phosphonic acid has been shown to boost the plant's resistance to the disease.

Dieback has severely affected plants which the Honey Possum depends on.

Fire

Even though Honey Possums have been observed in recently-burnt bushland, they may not be able to survive there as food resources may be insufficient to sustain a stable population.

Recolonisation may occur if Honey Possums are present in nearby bushland, but it may take many years for the population to achieve its former level.

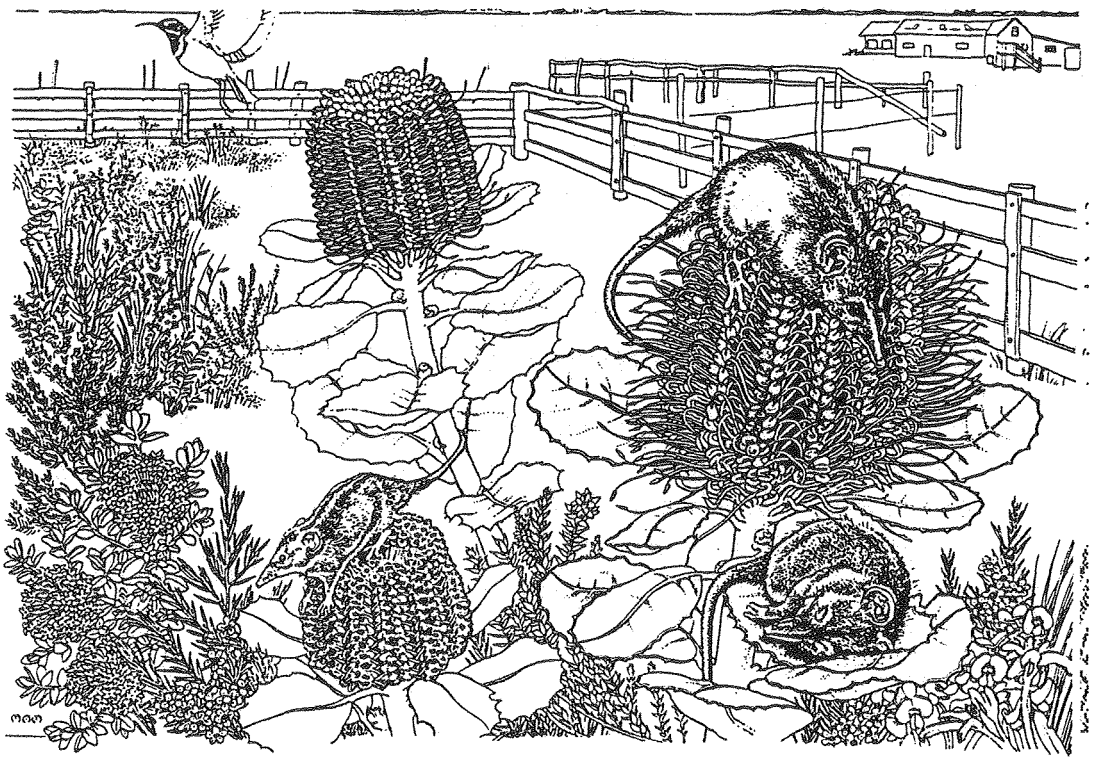


Figure 3. The Honey Possum and its Web of Life.

The Honey Possum is not likely to be able to recolonise the area if the whole of the vegetation remnant has been burnt and is isolated from other areas of bush.

Fire may reduce populations of both the Honey Possum and its food plants.

Wildflower Picking

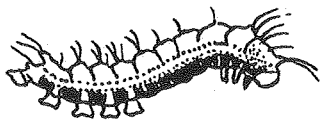
Plants of the banksia family are sought by wildflower pickers who cut the flowers, thus reducing the amount of food available for the Honey Possum. Flowers of the Hooker's Banksia, the Albany Banksia and the Baxter's Banksia are still being picked, removing the nectar supply from Honey Possum populations at the peak of the breeding season.

Wildflower picking takes away the food of the Honey Possum.

Predation

Cats are known to kill Honey Possums. People who live near bushland often find out about resident Honey Possums when their cat brings home a dead possum.

Cats kill Honey Possums.



Species List

List of the species connected to Honey Possums with their common and scientific names.

Type of organism	Common name	Scientific name
Plants		
Proteaceae	Albany Banksia	*Banksia coccinea*
	Baxter's Banksia	*Banksia baxteri*
	Bull Banksia	*Banksia grandis*
	Gardner's Banksia	*Banksia gardneri*
	Hooker's Banksia	*Banksia hookeriana*
	Nodding Banksia	*Banksia nutans*
	Oak-leaved Banksia	*Banksia quercifolia*
	Slender Banksia	*Banksia attenuata*
	Showy Dryandra	*Dryandra formosa*
	Coastal Jugflower	*Adenanthos cuneatus*
Myrtaceae	Bottlebrush	*Beaufortia anisandra*
	The common name: honeymyrtle, bottlebrush, ti-tree or paperbark, varies according to the species.	*Melaleuca* spp.
Root fungi	Dieback	*Phytophthora* spp.
Birds	Purple-crowned Lorikeet	*Glossopsitta pusilla*
	Red Wattlebird	*Anthochaera carunculata*
	Little Wattlebird	*Anthochaera lunulata*
	New Holland Honeyeater	*Phylidonyris novaehollandiae*
Mammals	Feral cat	*Felix catus*

Table 1. Species list for the Honey Possum web of life.

What We Can Do

The Honey Possum may join the list of threatened species if we do not take action to protect it.

The Honey Possum is part of a fragile web of life and its disappearance may have an adverse impact on the plants that are pollinated by this small mammal.

Some plants depend on the Honey Possum for pollination.

There is a lot we can do to help the fragile Honey Possum web of life. We can:

- join a local conservation group which aims to conserve remnant vegetation and Honey Possum habitat;
- ask authorities to only use prescribed burning if absolutely necessary and to retain large areas of unburnt bush, with nectar-producing wildflowers in bloom all year round, as Honey Possum refuge;
- lobby authorities to reduce commercial wildflower picking in Honey Possum habitat, so that the Honey Possum's nectar supply is not depleted;
- keep domestic cats inside at night. A 'cat curfew' is one of the best things a family can do to help local wildlife. Three bells on the collar will warn other wildlife.

Suggested Activities

Who Killed Honey Possum?

The teacher plays the role of Chief-Inspector and introduces the year as 2099 AD. One of the Great Mysteries of the world needs to be solved - Who Killed Honey Possum?

Students are enlisted as detectives.

Give each student a 'Clue-Pack' containing a picture of a Honey Possum, some pollen and Banksia. They must first identify each clue/picture - labelling it and explaining the relationship between the clues.

When they have completed this, they can receive the next clue - the 'secret' word 'Wildflowers'.

Using the clue, they must record the relationship between Wildflowers and Honey Possum. A list of possible 'suspects' (types of wildflowers involved) should be drawn up and an explanation of why there is more than one wildflower involved in the mystery.

Once this is complete, the next clue is given - Figure 2 Distribution of the Honey Possum from the Case Study. Students to write notes on the relevance of this clue.

On completion of this part of the activity, show a picture of a bulldozer, a cat, a fire and the word 'Dieback'. Again notes are to be taken on the relevance of these things.

Using the information gathered, students to suggest ways that we can help save the Honey Possum. Teacher to record the suggestions on the board or a large piece of paper. Each student to select ONE of the suggestions and make a poster explaining the problem and what we can do to help solve it.

Application to the Student Outcome Statements

English - Speaking and Listening; Reading; Writing

Science - Investigating Scientifically

Extension Activities for Students

Science, and Society and Environment

1. Find out which plants are affected by the dieback disease. How is dieback spread? How is the disease affecting the survival of the Honey Possum and what can be done to protect Honey Possum habitat from dieback?
2. Visit the following website on the Internet: http://www.evolve.net.au/natives and search pages on Proteaceae and Myrtaceae. Find photos of some of the plant species mentioned in the text. Which species in your opinion are a good food source for Honey Possums?

The Arts and English

Art: create a 3D mural out of natural or recycled material based on the Honey Possum and its web of life. Materials can include wool, felt, milk and egg cartons, papier mache, string and wire. You can also use natural material from the bush, such as gumnuts, dead leaves and twigs.

Field Studies

1. Select an area of bushland near your school and find out about and decide on what plant species could provide food for the Honey Possum. Note the flowering season of each of these plants and, by plotting this information on a graph, find out if the flowering seasons overlap sufficiently for the Honey Possum to be able to obtain food all year round.
2. Find a flower of banksia, dryandra, grevillea, hakea or eucalypt in your backyard or a nearby patch of bushland (collect only one flower and not a whole flower blossom or number of flowers to avoid harming the plant).

   Draw a close-up of the various parts of the flower and find out what their names are. Identify the role of each part of the flower in the pollination process and find out how the Honey Possum feeds and also pollinates the flower.

   Collect some pollen from the stamens and observe it under a microscope. Compare the size and shape of pollen grains for different species of plants.

Further Reading

Hussey, B. M. J. and Wallace, K. J. (1993). 'Managing your Bushland'. Department of Conservation and Land Management, Como.

Johnson, B. and Thomson, C. (undated). 'Mammals of the South-west'. Department of Conservation and Land Management, Como.

Renfree, M. B. and Wooller, R. D. (1995). 'The Honey Possum'. In: Strahan, R. (Ed.). 'The Australian Museum Complete Book of Australian Mammals'. pp. 173-74. Cornstalk Publishing, Collins/Angus/Robertson.

Schodde, R. and Tidemann, S. C. (Eds). (1997). 'The Reader's Digest Complete Book of Australian Birds'. Reader's Digest Publ., Sydney.

Contacts

Curtin University, School of Environmental Biology, C/- Prof. Byron Lamont, Tel. (08) 9351 7368.

Murdoch University, School of Biological Sciences, C/- Assoc. Prof. Ron Wooller, Tel. (08) 9360 2250.

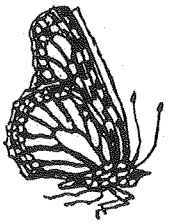
University of Western Australia, Department of Zoology, C/- Prof. Don Bradshaw, Tel. (08) 9380 2227.

WA Gould League, Herdsman Lake Wildlife Centre, Tel. (08) 9387 6079.

Western Australian Herbarium, Tel. (08) 9334 0500.

Wildflower Society of Western Australia, Tel. (08) 9383 7979.

Glossary



Distribution

Geographic area where a species is present.

Ecosystem

Term used to describe a specific environment and all the interconnections between its different parts, including animals, plants and micro-organisms.

Heathland

Vegetation type characterised by a dense, low cover of shrubs usually no more that 2.0 m high.

Habitat

Part of an ecosystem used by a species for its breeding, feeding and resting needs.

Home range

Area or living space used by a particular animal for all of its activities over an extended period of time. The 'Home range' is different from the animal's 'Territory', an area usually actively defended against other individuals of the same or different species.

Marsupials

One of the three sub-classes of mammals (with placental mammals and monotremes). Unlike placental mammals, marsupials do not have a well-developed placenta. Marsupials give birth to young in an incomplete state of development some 2 to 5 weeks after conception. The young attaches itself to one of the teats of the mother (sometimes inside a pouch, but not always) and remains there until it becomes able to feed itself.

Nectar

Nectar is a sugary substance produced by plants to attract pollinators (insects, mammals, birds) to their flowers. It is a 'reward' for the pollinator which, in return, carries pollen from one flower to another, a 'service' essential for the reproduction of many plant species.

Pollen

Grains produced by the stamens that contain the male reproductive cells that take part in the fertilisation of the female ovules, themselves contained in the ovary of the plant.

Prescribed burning

A burning operation in bushland deliberately lit and controlled by humans, usually as part of a land management program; for example, to reduce the chance of uncontrollable bushfires or to control weeds.

Recolonisation

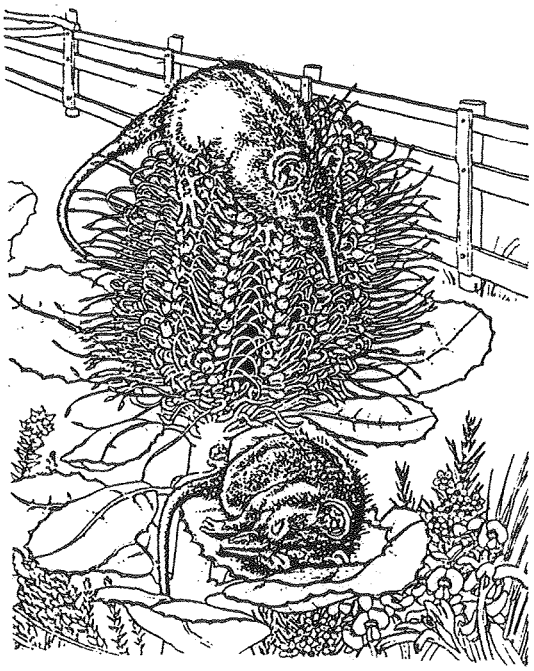
Re-invasion by a plant or animal species of an area within its range from which it had previously disappeared.

Threatened

A species or community that is vulnerable, endangered or presumed extinct.

Woodland

Vegetation type characterised by an open upper canopy of trees or shrubs of varying heights and density (10 - 30% cover), with an understorey of smaller shrubs, herbs and grasses, e.g. banksia or eucalypt woodland.



Case Study 4
Vanishing Carnaby's Cockatoos

What is Biodiversity?

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Biodiversity is the variety of life forms which exist on the Earth.

Biodiversity includes not only the plants and animals that we see around us (including ourselves), but also the myriad of microscopic organisms that inhabit our environment, such as fungi, algae, bacteria and viruses.

Most of the Earth's biodiversity consists of a large number of invertebrates, fungi, bacteria and non-flowering plants. Vertebrate animals and flowering plants represent only a small fraction of the total biodiversity, probably less than 1% in number of all species on Earth.

Carnaby's Cockatoo's Web of Life

Carnaby's Cockatoo's web of life is linked to the continued existence of eucalypt woodlands which provide the birds with hollows for nesting, and of heathlands which contain various species of banksia, dryandra, grevillea and hakea that provide food (seeds, wood-boring larvae) for the birds. Some banksias, including the Lesueur Banksia, a rare species found in and around Mt Lesueur National Park, benefit from the cockatoos feeding on the wood-boring grubs because the cockatoos reduce larvae outbreaks that could consume the flower heads and prevent the plant from reproducing.

Carnaby's Cockatoo depends on eucalypt woodlands and nearby heathland.

The Carnaby's Cockatoo is an important part of a highly diverse natural community with which the cockatoo is closely connected. Heathlands and woodlands form a rich web of life which includes not only Carnaby's Cockatoos, but also Honey Possums and honeyeaters which play a major role in the pollination of native flowers (see the Honey Possum Case Study).

Numbers of Carnaby's Cockatoo have greatly decreased because of land clearing and the decline of remnant vegetation, and its range has contracted by more than 30% over the last 30 years. Although the cockatoos have taken advantage of pine plantations that provide them with abundant food, in the form of seeds in pine cones, outside the breeding season their future is uncertain unless more feeding habitat can be provided within a short distance of nesting hollows.

Numbers of Carnaby's Cockatoo have declined due to land clearing and a reduction in remnant vegetation.

What Do We Know About the Carnaby's Cockatoo?

In the days of the Swan River Colony, early settlers reported that it was not uncommon to see flocks of white-tailed black-cockatoos at migration time that blacked out the sky. A single flock may have numbered in the tens of thousands, with a total population estimated in the hundreds of thousands.

Figure 1. Carnaby's Cockatoo web of life.

Even in the late 1970s, it was not uncommon to see flocks of several thousand birds in and around the Metropolitan area.
Nowadays, Perth residents can still enjoy the familiar sight and sound of flocks of white-tailed cockatoos with their slow wing beats and loud screeches.

Since European settlement the population of Carnaby's Cockatoo has been drastically reduced.

However, the total population probably now numbers only 10,000 to 20,000 birds, and flocks of several hundred are regarded as large. One day, these majestic birds may vanish altogether from our skies as their breeding and feeding habitat is increasingly under threat and their breeding range is greatly reduced.

Carnaby's Cockatoo is one of two species of black cockatoos with white tails native to Western Australia. Carnaby's Cockatoo (short-billed species) breeds in the Wheatbelt in Spring and migrates towards the coast in Summer–Autumn.

Baudin's Cockatoo (very similar, but with a longer bill and a different diet) breeds in the more humid forested South-west corner. The ranges of both species overlap and both can be seen in the Perth area in Autumn.

Carnaby's Cockatoo is a long-lived, slow-breeding species which has specific food and nesting requirements.

The Carnaby's Cockatoo

Aboriginal names: Oo-lack (Perth); Ngo-lak, Ngol-ye-nuk (Avon River); Woo-lock (Albany); Gnular (Pallinup River); the names are reminiscent of the call of the bird.

Scientific name: *Calyptorhynchus latirostris*.

Family: Psittacidae (parrots and cockatoos).

Size: 50–60 cm, wingspan 1 m.

Weight: 660 g.

Longevity: 40–50 years in the wild and 60–70 years in captivity.

Conservation status: classified as 'Rare or threatened with extinction' under the Western Australian law and Vulnerable according to the IUCN (World Conservation Union).

Carnaby's Cockatoo is one of two species of white-tailed black cockatoos found in the South-west.

Diet

Carnaby's Cockatoos mainly eat the seeds in the woody fruits of banksias (e.g. Acorn Banksia), dryandras (e.g. Parrot Bush), grevilleas and hakeas, which are all plants of the family Proteaceae. The seeds found in the cones of pine trees are also eaten in large quantities during migration time; that is why large flocks of several thousand cockatoos can be seen in the Gnangara and Yanchep pine plantations north of Perth in Autumn and early Winter.

Carnaby's Cockatoo eats the seeds of plants of the family Proteaceae.

Carnaby's Cockatoos are also fond of wood-boring larvae found in the flower heads of banksias and in the trunks of eucalypts. One of these larvae comes from the native moth *Arthrophora* that attacks the flower heads of the Lesueur Banksia. By removing the larvae, the cockatoo helps control the numbers of the parasitic grubs. Even though large numbers of flower heads can be destroyed by the cockatoos in this process, this does not appear to harm the banksias as most flower heads would have been made infertile if the larvae had survived.

Carnaby's Cockatoo also eats wood-boring larvae.

Distribution

Carnaby's Cockatoos inhabit the Wheatbelt during the breeding season (July–December), then move towards the coast where they spend the Summer–Autumn–early Winter. This is when they are most commonly observed in Perth. Their current distribution is shown in Figure 3.

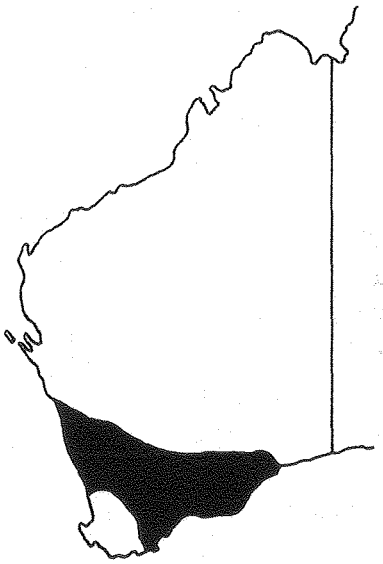


Figure 3. Distribution map of the Carnaby's Cockatoo.

Carnaby's Cockatoo migrate to the coastal areas during Summer-Autumn.

Habitat

The Carnaby's Cockatoo breeds in the hollows of large trees, particularly Wandoo, Salmon Gum, Gimlet and York Gum. Trees need to be at least 100–150 years old to have hollows

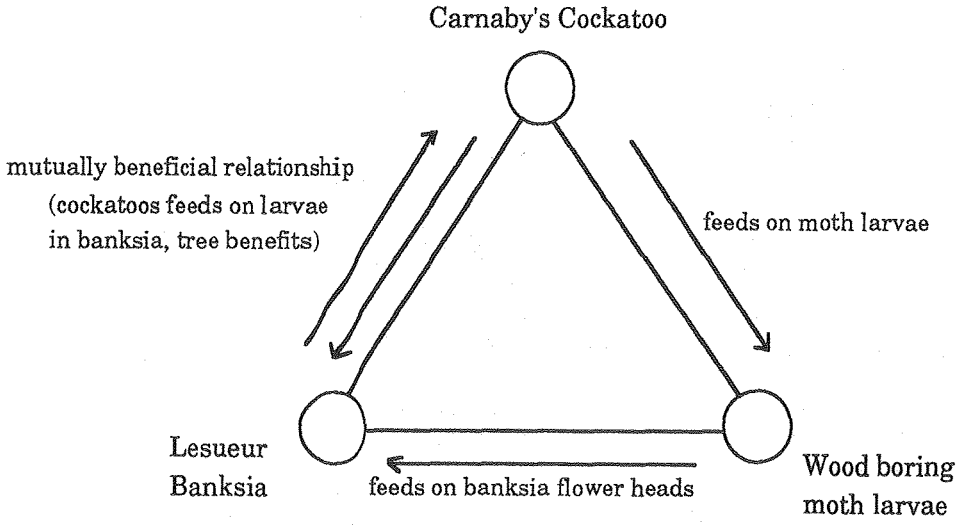


Figure 2. The relationships between Carnaby's Cockatoo, banksias and moths.

large enough for the Carnaby's Cockatoo to nest in. Dead or dying trees often provide valuable hollows for the cockatoo. The bird also needs heathland vegetation close to the nest (within two kilometres), so that the parents can find enough food close to their young nestling.

Carnaby's Cockatoo breeds in the hollows of gum trees.

After breeding, Carnaby's Cockatoos move towards the coast into bushland with banksia, dryandra, grevillea and hakea vegetation. In Perth, Carnaby's Cockatoos favour Parrot Bush (*Dryandra sessilis*) bushland and have also taken advantage of the large areas of pine plantations around the Perth Metropolitan area.

Carnaby's Cockatoo feeds on heathland plants near the coast.

Reproduction

Two eggs are laid and incubated, but the second hatchling usually dies after 48 hours. The surviving chick leaves the nest after 10 to 11 weeks. If the adults cannot obtain enough food for their offspring, breeding is unsuccessful. Young are dependent on their parents for food until the parents start to breed again next season. Carnaby's Cockatoos do not start breeding until they are four years old. They pair for life.

Usually, only one offspring survives.

What Happened to the Carnaby's Cockatoo?

The Carnaby's Cockatoo is not found anymore in the eastern part of its former range and does not breed anymore in many areas of the Wheatbelt. Detailed studies of the Carnaby's Cockatoo, conducted by Dr Denis Saunders of the CSIRO Division of Wildlife and Ecology over the last 30 years, have shown that the cockatoo's decline is related to the decline of the native vegetation in the Wheatbelt.

The decline of Carnaby's Cockatoo is directly related to the decline of native vegetation.

A Vanishing Habitat

Clearing and Remnant Vegetation Decline

In the last 150 years, most of the native vegetation in the Wheatbelt and the Swan Coastal Plain has been cleared for agriculture, mining and urban development. What was a continuous area of bushland is now reduced to small 'islands' of remnant vegetation (see Figure 4). Breeding cockatoos have to go further to

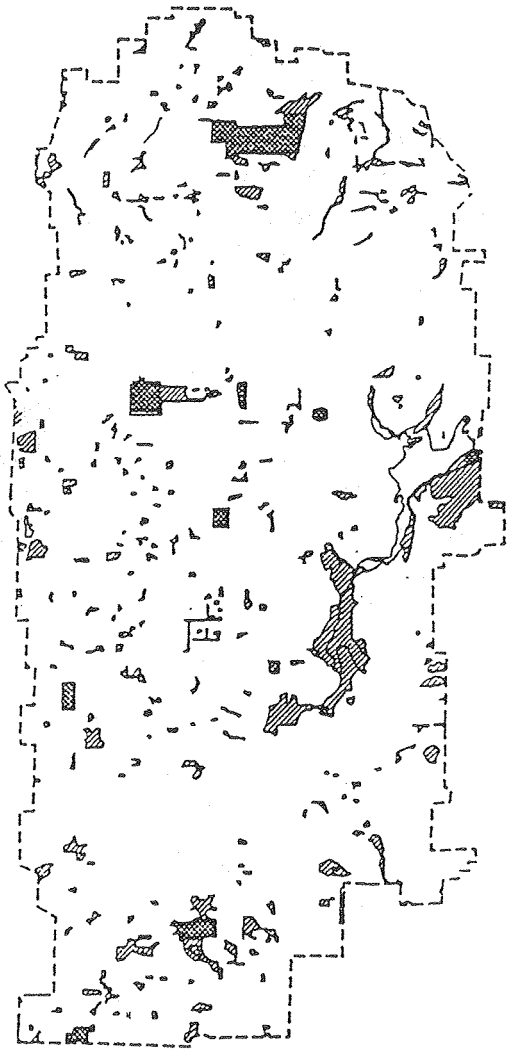


Figure 4. Shire of Tammin - Remnant vegetation map.

Land clearing for agriculture, mining and development have reduced the Carnaby's Cockatoo habitat.

find food for their chicks which often die from starvation. Many old trees have disappeared and cockatoos have to compete for the remaining breeding hollows with the large numbers of Galahs and corellas, which have colonised the Wheatbelt from the arid interior and pastoral areas.

In addition, grazing by sheep, frequent fires and weeds prevent the natural regeneration of the native bushland, including native heathland species that provide food for the bird. This means that not enough trees reach an age when they have hollows big enough for cockatoos to breed in and heathland is not abundant.

Many factors have contributed to the decline of Carnaby's Cockatoo.

Scientists do not know the proportion of young, adult and ageing birds in current populations of Carnaby's Cockatoo, but they suspect that many birds are old and that not enough young birds are produced to replace the ones that die. If this is the case, it would be very difficult to reverse the bird's decline, and extinction is a real possibility.

Other Human Impacts

Cockatoos are protected by law and it is illegal to capture or disturb cockatoos, their eggs or their young. However, wildlife traffickers still remove cockatoo chicks and eggs and often destroy precious nesting hollows by cutting the side of the trunk where the nest is located. Cockatoos command a high price on the black market in Australia and overseas.

Other threats to the Carnaby's Cockatoo include feral cats taking chicks from the nest and birds being killed by passing traffic when feeding on roadside vegetation, often the only areas of native vegetation left in rural regions.

Feral cats and human activities have contributed to a population decline of Carnaby's Cockatoo.

Decline of Other Cockatoos in the South-west

The Carnaby's Cockatoo is not the only species of cockatoo to have declined in the South-west. Two forest-dwelling species, Baudin's Cockatoo and Forest Red-tailed Black-Cockatoo, have also suffered major reductions in numbers and are under threat from agriculture, logging, mining and urban expansion. The Major Mitchell Cockatoo (also called Pink Cockatoo for its beautiful pink underside and crest) used to be widespread in the Wheatbelt and now breeds in only a few areas.

Many other cockatoo species are at risk of extinction.

What We Can Do

There are many things that we can do to help the Carnaby's Cockatoo. The best things we can do are to conserve the cockatoo's habitat and preserve remnant vegetation in general. We can:

- help create new reserves in the Wheatbelt and on the Swan Coastal Plain that contain cockatoo feeding and breeding habitats;
- ensure that bushland used by cockatoos for breeding and feeding is retained and protected and that these areas are connected by vegetation corridors;
- protect all old trees with hollows, particularly Wandoos, Gimlet, Salmon and York Gums;
- conserve roadside vegetation which often contains mature trees with hollows and heathland vegetation;
- fence off remnant vegetation and creeklines;

The best way to help the Carnaby's Cockatoo is to save its habitat.

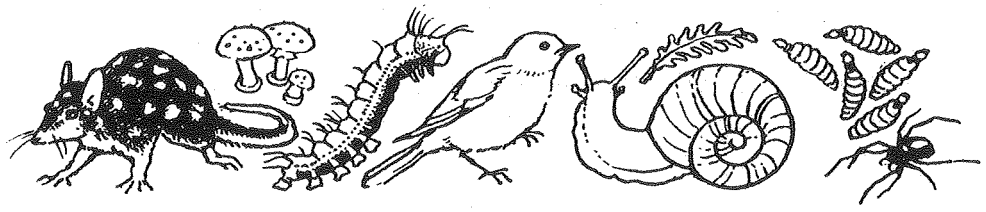
- grow plant species that will provide food and breeding hollows for the cockatoos in future and plant these species wherever possible;
- report to CALM wildlife officers or the police any suspicious activity in country areas indicative of poaching (for example, vehicles driving on remote roads and carrying ladders).

Species list

The species mentioned in the text are listed here with their common and scientific names.

Type of organism	Common name	Scientific name
Birds		
	Carnaby's Cockatoo	*Calyptorhynchus latirostris*
	Baudin's Cockatoo	*Calyptorhynchus baudinii*
	Forest Red-tailed Black -Cockatoo	*Calyptorhynchus banksii naso*
	Major Mitchell Cockatoo	*Cacatua leadbeateri*
	Galah	*Cacatua roseicapilla*
	Long-billed Corella	*Cacatua pastinator*
	Little Corella	*Cacatua sanguinea*
Mammals		
	Feral cat	*Felix catus*
Plants		
	Lesueur Banksia	*Banksia tricuspis*
	Acorn Banksia	*Banksia prionotes*
	Wandoo	*Eucalyptus Wandoo, E. capillosa*
	Salmon Gum	*Eucalyptus salmonophloia*
	York Gum	*Eucalyptus loxophleba*
	Gimlet	*Eucalyptus salubris*
	Parrot Bush	*Dryandra sessilis*
	Pine (various introduced species)	*Pinus* spp.
Insects		
	European Honey Bee (introduced)	*Apis mellifera*
	Wood-boring moth larvae	*Arthrophora* spp.

Table 1. Species list for Carnaby's Cockatoo's web of life.



Suggested Activities

The Tale of Carnaby's Cockatoo - a Picture Book for Primary Students

Create a picture book for primary school students that tells the story of the Carnaby's Cockatoo. The picture book would be presented as fiction but students must ensure that **all** the information included is factual, based on the notes provided.

(Alternatively, students could produce a non-fiction picture book on the subject which may be more applicable to Society and Environment.)

Work as individuals, pairs or small groups.

Lead a discussion with students talking about the birds they see around their area. Ask them how many cockatoos they see. Students identify the characteristics of the cockatoo that they have seen and note what they like and dislike about the cockatoos.

Brainstorm the human qualities that could be ascribed to a cockatoo - what sort of person could be described as a cockatoo?

Outline the picture book assignment.

Provide students with an overview of the information that **must** be included in the picture book - e.g. habitat, diet, distribution, physical characteristics, reproduction, things that humans can do.

Students take notes for each of these headings to ensure that they understand the information provided.

As a whole class, identify the possible conflict or issue that could be the focus of the story and ways that this could be resolved.

Ask students to work in pairs or groups to suggest possible approaches to the story and pictures based on the information they are required to include. If the classroom environment is conducive to positive criticism, ask each group to put forward their suggestions and have other students comment on the ideas (alternatively, get two or three groups to combine for this part of the planning).

Once the picture books are completed, students should have the opportunity to present their picture books to a group of primary school children.

Who Cares About Carnaby's Cockatoo?

Working in small groups, students create a computer game or board game that is based on the story of the vanishing Carnaby's Cockatoo.

The game should be kept simple and short but should include a series of 'helps' and 'hazards' encountered by the Cockatoo. Particular emphasis on the interactions between the Carnaby's Cockatoo and the environment should be apparent.

The aim of the game should be to introduce the information about the Carnaby's Cockatoo, including its diminishing living area in a fun way to other people.

In addition to the game, they should produce a comprehensive instruction manual for a beginner to use. (This could be an activity in its own right). The manual should include illustrations, explanations of certain things such as land clearing, as well as creating issues for the Carnaby's Cockatoo.

Once the games have been completed, they should be trialed by other students.

Application to the Student Outcome Statements

Arts - Using Arts Skills, Techniques, Technologies and Processes; Communicating Arts Ideas

English - Speaking and Listening (Contextual Understanding, Use of Texts, Processes and Strategies); Reading (Contextual Understanding, Use of Texts); Writing (Contextual Understanding, Use of Texts, Processes and Strategies)

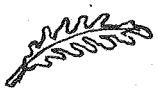
Technology and Enterprise - Devising; Producing

Science - Life and Living

Extension Activities for Students

Science, and Society and Environment

1. Look at the map of the remnant vegetation in the Shire of Tammin (Figure 4). Give five suggestions as to why Carnaby's Cockatoo has stopped breeding in the Shire. What do you think could be done to bring back Carnaby's Cockatoo to Tammin?
2. Why is preserving biodiversity and Carnaby's Cockatoo important? Give three reasons why you think we should help conserve this web of life. Describe five actions we can take to help the cockatoo. Indicate which ones are most urgent and explain why.
   - how many threatened bird species (vulnerable, endangered and extinct) are there in Australia and which of these occur in Western Australia?
   - what are the threats to Carnaby's Cockatoo and other threatened birds?
   - what is being done to save these species?
3. Threatened birds on the Internet. Visit the following websites:
   - http://www.vicnet.net.au/~birdsaus/threat.html.
   - http://www.biodiversity.environment.gov.au/plants/threaten/index.htm.
   - http://www.perthzoo.wa.gov.au/cc.html.
   - http://www.nccnsw.org.au/member/tsn/

   Compile a summary of the facts relevant to threatened birds and Carnaby's Cockatoo.
4. Banksias on the Internet. Visit the following website:
   - http://www.evolve.net.au/natives/

   Find the page on the banksia family (called Proteaceae) and summarise the information on the acorn banksia.

The Arts and English

Art: Create a mural depicting the Carnaby's Cockatoo's habitat: old Wandoo trees with hollows for nesting and flowering banksias and Parrot Bush for feeding. Represent the connections of the Carnaby's Cockatoo with other animal and plant life in the bushland.

Drama: Make puppets out of recycled materials portraying Carnaby's Cockatoo, the banksia tree, the wood-boring moth larvae and two human characters, one from the city and one from the country. Create a puppet show based on the story of the cockatoo described in this case study.

Field Studies

1. Visit a bushland area near your school where Carnaby's Cockatoo is often seen feeding. Birds Australia or CALM may help you identify such an area (see contact details below).
   - Map the bushland and identify the area available for the cockatoo to feed.
   - Calculate the proportion of the total bushland area available as habitat for the species. How could this area be increased?
2. Grow banksia, dryandra, grevillea and hakea seedlings for planting in bushland in Perth and in the Wheatbelt to provide a food source for the cockatoos. Grow Wandoo, Gimlet and Salmon Gum seedlings to provide nesting trees for cockatoos (it will take over 100 years for these trees to form hollows, but we need to start now). Contact APACE, the Men of the Trees (and the Millions Trees Project) to find out what is required to establish a tree nursery.

   Plan what you need to do to develop an exchange program and joint activities with a country school to restore an area of bushland for the Carnaby's Cockatoo in the Wheatbelt.
3. Visit the Perth Zoo as a class excursion and go to the Cockatoo Information Centre. Make a booking with the Perth Zoo Education Centre to take part in the "Cockies in Crisis" activity; extra teacher resources will be supplied.

Further Reading

Garnett, S. (1992). 'The Action Plan for Australian Birds'. Australian National Parks and Wildlife Service, Canberra. Document available on the website: http://www.biodiversity.environment.gov.au/plants/threaten/plans/action_plans/australian_birds/index.htm

Hussey, B. M. J. and Wallace, K. J. (1993). 'Managing your Bushland'. Department of Conservation and Land Management, Como.

Perth Zoo Education Centre. (1995). 'Carnaby's Cockatoo', Leaflet and teaching notes.

Schodde, R. and Tidemann, S. C. (Eds). (1997). 'The Reader's Digest Complete Book of Australian Birds'. Reader's Digest Publ., Sydney.

Saunders, D. A. and Ingram, J. A. (1987). 'Factors affecting survival of breeding populations of Carnaby's Cockatoo *Calyptorhynchus funereus latirostris* in remnants of native vegetation'. In: Saunders, D. A. et al. (Eds). 'Nature Conservation 1. The Role of Remnants of Native Vegetation'. pp. 249–58. Surrey Beatty & Sons. Chipping Norton, NSW.

Saunders, D. A. and Ingram, J. A. (1995). 'Atlas of the Birds of Southwestern Australia'. CSIRO Publishing, Collingwood, Victoria.

Contacts

Birds Australia - WA Group, Tel. (08) 9383 7749.

CSIRO, Division of Wildlife and Ecology, Tel. (08) 9333 6200.

Environment Australia, Community Information Unit, Canberra, Tel. (FREECALL) 1800 803 772.

Perth Zoo, Education Centre (c/- Sue Boland), Tel. (08) 9474 0399.

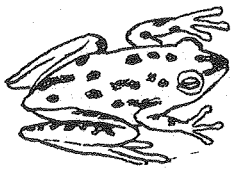
Threatened Species Network, Tel. (08) 9387 6444.

WA Gould League, Herdsman Lake Wildlife Centre, Tel. (08) 9387 6079.

Western Australian Museum (c/- Ron Johnstone), Tel. (08) 9427 2700.

You can get help for growing native plants such as banksia, dryandra and eucalypts from:

- **APACE Western Australia**, Tel. (08) 9335 1262.
- **Men of the Trees**, Tel. (08) 9274 2875.



Glossary

Distribution
Geographic area where a species is present.

Ecosystem
Term used to describe a specific environment and all the interconnections between its different parts, including animals, plants and microorganisms.

Endangered
Species in danger of extinction unless measures are taken to prevent its decline.

Extinct
Species that has not been seen in the wild for at least 50 years.

Habitat
Part of an ecosystem used by a species for its breeding, feeding and resting purposes.

Migration
Seasonal movement of an animal population from one area to another area that occurs every year.

Parasitic
Describes an organism that obtains its food from the body of another species (the host) without killing it directly.

Species
A group of plants, animals or micro-organisms that have a high degree of similarity and generally can interbreed only amongst themselves to produce fertile offspring, so that they maintain their 'separateness' from other such groups.

Threatened
A species or community that is vulnerable, endangered or presumed extinct.

Vulnerable
Species which is likely to become endangered if its current decline continues.

Weed
A plant species growing where it is not wanted by humans.

Case Study 5
Estuaries, Mudflats and Migratory Waders

What is Biodiversity?

Biodiversity represents the sum of all living organisms, such as plants, animals and micro-organisms, their genetic variations and their interconnections within complex ecosystems.

Biodiversity exists everywhere: in forests, mountains, deserts, lakes, rivers and oceans. It is present in cities, houses and backyards, on farms and in any human modified environment, as well as around our bodies, on our skin and in our internal organs.

Biodiversity is the variety of life forms which exist on the Earth.

Biodiversity includes not only the plants and animals that we see around us (including ourselves), but also the myriad of microscopic organisms that inhabit our environment, such as fungi, algae, bacteria and viruses.

Most of the Earth's biodiversity consists of a large number of invertebrates, fungi, bacteria and non-flowering plants. Vertebrate animals and flowering plants represent only a small fraction of the total biodiversity, probably less than 1% in number of all species on Earth.

Estuaries: a Hidden World of Biological Wealth

Estuaries are an important part of coastal environments in the South-west of Western Australia (Figure 1). Most South-west rivers flow into a shallow estuary that connects with the ocean through a channel. The channel is usually closed by a sand bar during the most of the year and opens in winter if there is enough rain.

An estuary connects a river to the ocean.

An artificial channel is sometimes dug to increase the flow of water between the ocean and the estuary; for example, the Dawesville Channel, south of Mandurah, linking the Peel Inlet with the ocean.

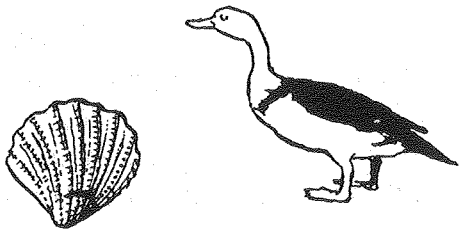
Estuaries are complex ecosystems that are habitats for a diversity of organisms, large and small (some of them so small that they are invisible to the naked eye): minute phytoplankton, bacteria, fungi, algae, tiny invertebrates (worms, shellfish, crustaceans, aquatic insects), many species of birds, a great variety of fish, and plants with remarkable adaptations to a highly variable environment.

Estuaries contain a large number of organisms.

Parts of an Estuary

There are many different ecosystems that make up estuaries:

- samphire flats, saltmarshes and mudflats;
- swamps and fringing reeds;
- islands, sandbars and sandpits;
- seasonal floodlands;
- open waters.



Many different eco systems are found in estuaries.

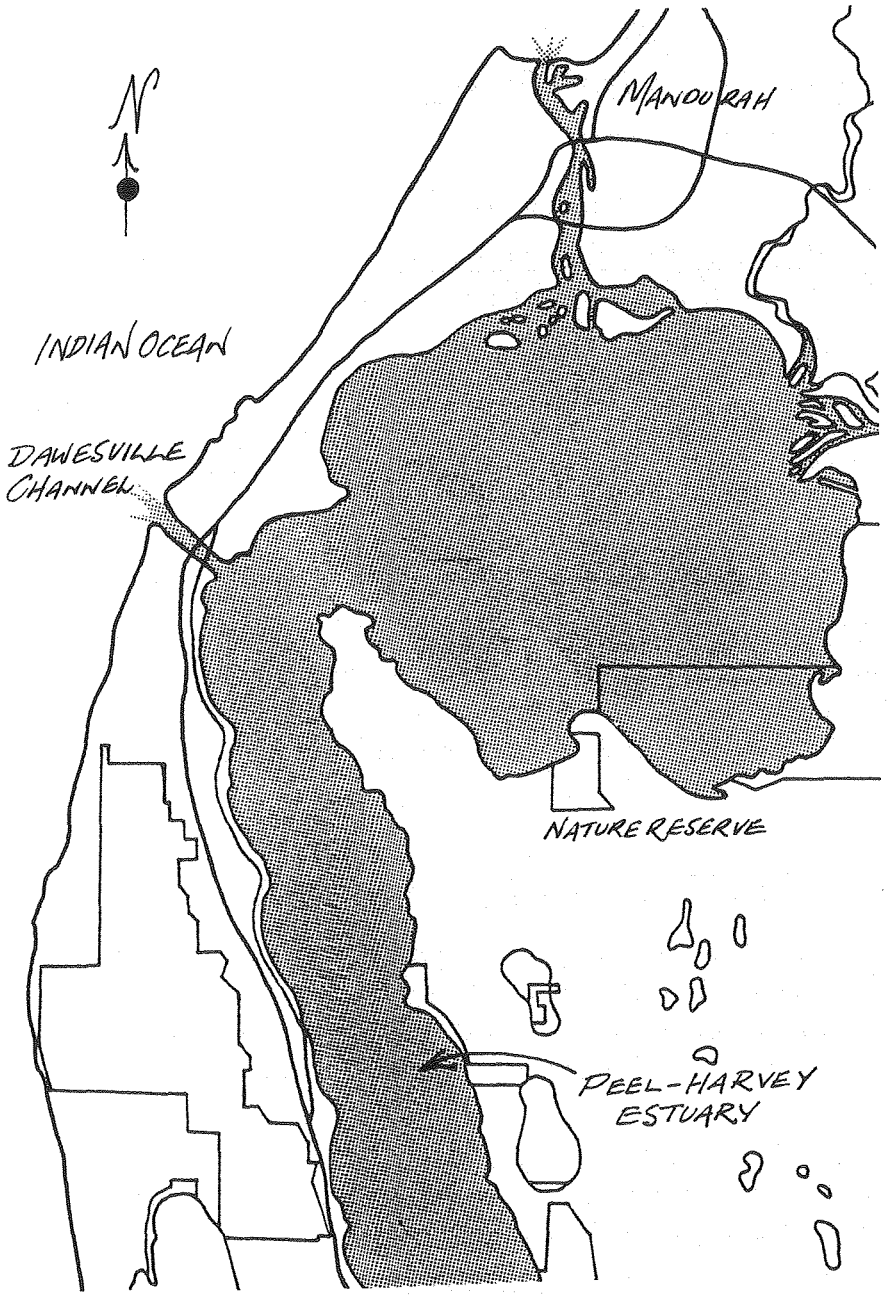


Figure 1. Map of the Peel-Harvey Estuary (Source: Peel Inlet Management Authority).

Samphire flats, saltmarshes and mudflats are a major component of most estuaries. Samphire are plants, adapted to saline environments, with thick fleshy round stems and no apparent leaves. Samphire flats, saltmarshes and mudflats support a large biomass of mud-dwelling invertebrates, which, in turn, provide food for great numbers of birds and other wildlife. Mudflats provide an essential habitat and food resource for many waders that visit the South-west estuaries from the Northern Hemisphere between September and April.

Samphire are plants that can tolerate a high level of salinity.

Open waters are used by many birds and fish. Estuaries contain pockets of permanently salty water in deeper areas, and the rest is of variable salinity depending on the tide, the flow of water between the ocean and the estuary, and the input of freshwater from streams and rivers flowing into the estuary. Fish have adapted to this diverse environment and many move between the estuary and ocean at certain times of the year.

Estuaries contain water of varying salinity, depending on tides and the flow of water.

The Role of South-west Estuaries in Conserving Biodiversity

Many wading birds depend on estuaries.

Each year, two million waders of 47 species reach Australian shores in their migration from northern Asia and Alaska. Waders are small shorebirds such as plovers, dotterels, sandpipers, stints and curlews that find their food in mudflats and saltmarshes.

Many waders breed in the Northern Hemisphere and migrate to the Southern Hemisphere to escape the harsh northern winter. They begin to arrive in the South-west in September. On their return migration, waders leave our shores in April to May and reach their breeding grounds in northern Asia in June. The Red-necked Stint and the Eastern Curlew have some of the longest migrations in the animal kingdom (see Figure 2).

Many waders migrate from the Northern Hemisphere to estuaries in the South-west.

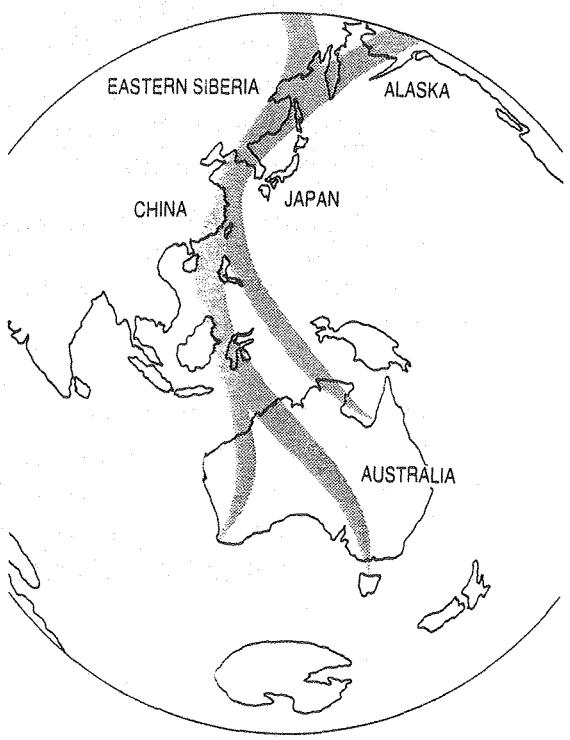


Figure 2. Migration of the Red-necked Stint (Source: 'Birdlife of South-west Estuaries', Information No. 3, Waterways Commission, 1990.

This extraordinary voyage extends over 10,000 kilometres and across 20 countries. Estuaries in the South-west play an essential role as Southern Hemisphere wintering grounds for waders.

Waders occur in great numbers and variety in the South-west estuaries. Up to 100 000 birds of 75 species, many of which would have been waders, have been recorded on the Peel-Harvey Estuary (near Mandurah) during a single bird count.

About 75 different bird species have been recorded in the Peel-Harvey Estuary.

Plants and Animals of South-west Estuaries

Here are some of the common animal and plant species that can be found in South-west estuaries.

Fauna

Birds

Waders rely on a complex web of life for their survival. Their beaks are different shapes and sizes to reach various invertebrates and molluscs in the mud. The length of their legs is suited to the depth of water in which they feed.

Waders differ in beak shape and leg length, depending on their food source.

Not all waders are migratory. Some waders, such as the Hooded Plover or the Pied Oystercatcher, breed and stay on Australian shores all year round.

Fish, Crabs, Shellfish and Other Invertebrates

Many fish, crabs and shellfish rely on estuaries for food and as nursery grounds. Juvenile fish can grow safely in estuaries; they represent up to 90% of the Tailor, Black and Silver bream, Skipjack Trevally, Snapper, Flathead, Whiting and Flounder caught in estuaries. Depending on their requirements, they inhabit different water depths with different levels of salinity. Black Bream is one of the few truly estuarine fish species and spends all its life cycle inside this highly variable environment.

Estuaries are important breeding and nursery grounds for many species of fish.

The Blue Manna Crab spends a large part of its life cycle in estuaries: as tiny crabs they enter the estuary to feed and grow to adult size in shallow regions. Fully-grown adults mate in the estuary, then females leave the estuary for the ocean to spawn.

Estuaries are habitat for a large variety of macroinvertebrates, such as marine worms, molluscs (snails, mussels), crustaceans (shrimps, prawns) and aquatic insects. A wide variety of microinvertebrates, such as tiny worms, filter-feeding crustaceans, and the larval stages of mosquitoes, flies and larger invertebrates, also live in estuaries. Microbial bacteria and fungi are also present and they break down organic matter from plants and animals.

Macro = large. Many invertebrates live in estuaries.

Microinvertebrates = small animals, often just visible with the naked eye.

Flora

Samphire flats, saltmarshes and mudflats contain a rich diversity of fauna and flora that are closely interconnected.

Larger Plants

The plants that grow in saltmarshes are adapted to a saline or brackish environment and some can survive under water for part of the year. The main salt-tolerant plants are:

- trees: Saltwater Paperbark, Flooded Gum, Saltwater She-oak, found near or around saltmarshes;
- shrubs: samphire, sea-heath, salt bush;
- sedges, herbs and grasses (such as Marine Couch).

Brackish = water that contains some salt.

Algae

Phytoplankton (tiny single-celled algae) are found mainly in the water and are an essential part of the food web of estuaries. Algae are an important food for macro and microinvertebrates. Outbreaks of blue-green algae and dinoflagellates (another type of single-celled algae) are caused by excess nutrients and can make the water unsafe for animals and humans to drink or swim in.

Blue-green algae may cause water to become unsafe to humans and animals alike.

Fungi and Bacteria

Fungi and bacteria play a key role in the decomposition of the organic plant and animal matter that comes from water catchments surrounding the estuary. Much of this runoff comes from farms and contains waste products from livestock.

Fungi and bacteria are decomposers - they break down organic matter.

The product of decomposition is, in turn, a food source for many invertebrates in the estuary that make up the base of the food chain for the larger species.

Estuaries - a Fragile Environment Under Pressure

Environmental problems in estuaries originate in rivers, streams and catchments that are often a long way from the coast. Thus, it is important to address human impacts where they occur, from the headwaters of rivers all the way to the coast.

Urban and Industrial Development

New suburbs, canal estates, marinas, roads and industrial developments are often established at the expense of wetlands, saltmarshes and mudflats. Critical habitat for migratory waders and fish are lost in the process.

New human developments may remove essential habitat areas for birds.

Pollution

Estuaries concentrate pollution caused by waste waters from urban areas, the dumping of toxic waste from industry and runoff containing agricultural pesticides and fertilisers. These effects on estuaries can be made worse by the contamination of the water table by pollutants which can eventually seep into estuaries.

Pollutants are detrimental to life in estuaries.

Nutrient Enrichment

Organic sediment and fertiliser runoff from pastures and intensive feedlots increases the amount of nutrients going into estuaries, causing excessive growth of phytoplankton and blue green algae. This leads to a loss of oxygen in the water, and results in the death of fish and other aquatic fauna.

Excess nutrients in estuaries cause algae overgrowth and oxygen depletion.

Changes to Estuary Water Flow

A lack of natural water exchange between the estuary and the ocean can lead to an excess of nutrients in the estuary and cause algal blooms. Opening a channel to the ocean may assist with this natural process. However, it is not clear how an artificial channel affects the life cycles of aquatic fauna and flora within the estuary.

Disturbance of Wildlife by Humans

People living around estuaries can disturb feeding waders and nesting birds. Dogs, four-wheel-drive vehicles, jet skis and boats can chase wildlife away. For example, the Hooded Plover, a small wader which nests on sandy beaches, is particularly sensitive to being chased away by beach users, particularly dogs and vehicles, and is on the decline throughout Australia.

Human activities affectmigratary and nesting birds.

Conserving Estuaries and Saltmarshes

Many migratory waders are protected under international treaties, such as the Japan and China-Australia Migratory Bird Agreements. Wetlands of international importance are also listed under the Ramsar International Convention, which aims to protect wetlands of world-wide significance.

Nature reserves such as the Austin Bay Nature Reserve in the Peel-Harvey Estuary (see Figure 1) protect parts of these diverse estuaries. However, some important migratory wader habitats are not adequately protected and are being used for marinas, canal estates and housing subdivisions.

When mudflats and saltmarshes disappear, so do important feeding grounds for migratory waders and essential components of the estuary web of life. Waders cannot use other places to feed and may not be able to store enough body fat to fuel their return voyage to their breeding grounds in the Northern Hemisphere. Fewer waders stay the winter in the South-west than ever before. Thus, the survival of a large number of migratory birds may depend on the protection of the South-west mudflats and estuaries.

Mudflats and saltmarshes are essential habitat for many migratory birds.

What We Can Do

We can become responsible users of natural areas and share our space wisely with other living things. Whenever possible, we should walk rather than drive: it is the ideal way of getting to know the rich wildlife found around estuaries.

We can contribute to an improvement in water quality in estuaries by reducing the amount of chemicals and nutrients being discharged into the catchment from suburban backyards, farmland and industrial areas.

Reducing our use of chemicals will help improve water quality in estuaries.

By joining a rivercare or coastcare group we can contribute to conserving local estuaries. Many such groups exist and some are listed in the 'Contacts' section that follows. These groups often help protect estuaries by negotiating with government and conservation agencies for the protection of important areas of wetlands as nature reserves.

Suggested Activities

Student Government - the Land of Estuary

The aims of this activity is to put into practice the process of decision making within a Parliamentary debate, to engage students in speaking to a particular case, and to practice research skills for informed discussion.

Students to form a Parliament in the Land of Estuary. Each 'party' is to represent a particular aspect of the Estuary ecosystem - the majority party is the 'Humans' who must also be represented by a group of students.

The Parliament has to develop strategies to save the Estuary, taking into account all of the different needs of each group. Each 'party' will represent its case to the Parliament, explaining their special needs, the relationships with other 'parties' and the effect the Humans are having on the land.

A 'Speaker' should be elected to facilitate the discussion to ensure that it stays on topic and each party has time to present their case.

The teacher should record the main points made in some way that is visible to the class.

Once the cases have been presented, the Parliament should then decide on a series of practical strategies that the members of the class could actively undertake within their daily or community lives.

Students to discuss the impact of a 'majority' in the making of decisions.

Model Estuary

Make a three dimensional model of an Estuary environment. Representations of the types of plants and animals found in and around the estuary are to be incorporated in the model.

In addition, the model should include some representation of the various countries that migratory birds originate from to show the international dimension of the Estuary (e.g small flags of each country).

Emphasis in the project would vary depending on the subject area but it is of key importance that the factual information is accurate.

Application to the Student Outcome Statements

Society and Environment - Place and Space (Features of Places, People and Places, Care of Places); Natural and Social Systems (Natural Systems, Political and Legal Systems); Investigation, Communication and Participation (Conducting Investigations, Processes and Interpreting Information, Evaluating and Applying Findings);

English - Speaking and Listening (Use of Texts, Contextual Understanding, Conventions, Processes and Strategies); Reading (Use of Texts, Contextual Understanding, Processes and Strategies)

Extension Activities for Students

Science, and Society and Environment

1. Choose one of the parts of an estuary listed earlier: mudflat, swamp, beach or open water, and draw a web of life for the species found there.
2. Draw pictures of ten species of waders using the same scale. Notice the difference in overall size, bill length and shape, and length of the legs. What are the possible reasons for all these differences in terms of their feeding habits?
3. Draw ten different plants (trees, shrubs and ground species) that grow in saltmarshes. Note their leaf shape and size, and comment on their adaptations to this harsh environment, particularly windy, salty and hot conditions.
4. Map the migration of the Red-necked Stint on a world atlas and describe the various countries visited on the way, their climate and dominant coastal environments.
5. On the map of the Peel-Harvey estuary, find which areas are protected as part of a nature reserve or national park. Calculate the proportion of the estuary that is effectively protected.
6. Visit the website of the 'National Wetlands Program' website at: http://www.anca.gov.au/environm/wetlands/

   Describe either a research or management project aimed at conserving wetlands and migratory birds, or report on a publication or a newsletter related to the protection of wetlands.

The Arts and English

Drama: write and act out a play based on the travels of the migratory Red-necked Stint. Include the breeding ground of the wader in northern Siberia, its summer visit to the estuaries of the South-west of Western Australia and migration across Asia.

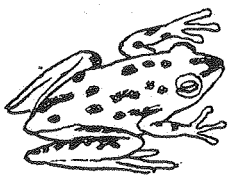
Art: create your own art work inspired by an estuary in a coastal landscape. Imagine and then blend the colours of the sky, the estuary, saltmarshes and mudflats, and shapes of plants and wildlife.

Field Studies

Visit a wetland or estuary near your school (if you live away from the coast, a swamp or creek bed would be suitable).

1. Note what the different types of habitat are and describe the vegetation in each habitat (trees, shrubs and ground vegetation) and the bird and insect life. Use direct observation, tracks in the mud and any other telltale signs for the presence of animals.
2. Record the various species of animals (such as insects, birds and mammals) that live in each habitat. Use a sieve to discover which animals live in the mud or in the water. Hint: use sieves of different mesh sizes to catch a variety of species. Sketch the various animals that you have observed in a note book and describe their habitat in a few words on the same page.
3. Start a Ribbons of Blue program in your school and monitor water quality in the wetland. The contact for your local Ribbons of Blue coordinator can be obtained from the nearest Water and Rivers Commission regional office.

Further Reading



On Estuaries

Chalmers, L. and Wheeler, J. (1997). 'Native Vegetation of Estuaries and Saline Waterways in south Western Australia'. Water and Rivers Commission and Department of Conservation and Land Management, Perth.

Fisheries Department of Western Australia. 'Estuaries: Our Fish Nurseries'.

Water and Rivers Commission. (1996). 'Macroinvertebrates and Water Quality'. Water Facts 2.

Water and Rivers Commission. (1997). 'River and Estuary Pollution'. Water Facts 3.

Latchford, J. (1994). 'Samphire Flats of the Peel-Harvey Estuary'. Peel Preservation Group.

Water and Rivers Commission. (1998).'Water Words'. Water Facts 1.

Water and Rivers Commission. (1998). 'Living Streams'. Water Facts 4.

Species List

List of the species commonly found in estuaries, with their common and scientific names. Migratory waders are marked by a 'star' (*).

Type of organism	Common name	Scientific name
Plants		
	Saltwater Paperbark	*Melaleuca cuticularis*
	Saltwater Sheoak	*Casuarina obesa*
	Flooded Gum	*Eucalyptus rudis*
	Samphire	*Halosarcia* and *Sarcocornia* sp.
	Sea heath	*Frankenia* sp.
	Salt bush	*Atriplex* sp.
	Sedges	*Juncus* and *Lepidosperma* sp.
	Marine Couch	*Sporobolus virginicus*
Birds		
Very large (>80 cm)	Black Swan	*Cygnus atratus*
	Australian Pelican	*Pelecanus conspicillatus*
Large (50–80 cm)	White-faced Heron	*Ardea novaehollandiae*
	Great Egret	*Egretta alba*
	Straw-necked Ibis	*Threskiornis spinicollis*
	Yellow-billed Spoonbill	*Platalea flavipes*
	Australian Shelduck	*Tadorna tadornoides*
Medium (30–50 cm)	Australian Grey Teal	*Anas gracilis*
	Black-winged Stilt	*Himantopus himantopus*
	Pied Oystercatcher	*Haematopus longirostris*
	Eastern Curlew*	*Numenius madascariensis*
	Bar-tailed Godwit*	*Limosa laponica*
Small (15–30 cm)	Grey Plover*	*Pluvialis squatarola*
	Grey-tailed Tattler*	*Tringa brevipes*
	Common Sandpiper*	*Tringa hypoleucos*
	Curlew Sandpiper*	*Calidris ferruginea*
	Red-necked Stint*	*Calidris ruficollis*
	Red-capped Plover	*Charadrius ruficapillus*
	Hooded Plover	*Charadrius cucullatus*
Fish		
	Tailor	*Pomatomus saltatrix*
	Whiting	*Sillago* sp.
	Black Bream	*Acanthopagrus butcheri*
	Silver Bream	*Rhabdosargus sarba*
	Flathead	*Platycephalus* sp.
	Skipjack Trevally	*Pseudocaranx dentex*
	Snapper	*Chrysophrys auratus*
	Flounder	*Pseudohombus* sp.
Crustaceans		
	Blue Manna Crab	*Portunus pelagicus*
	Western King Prawn	*Penaeus latisulcatus*
	River Prawn	*Metapenaeus dalli*

On Migratory Birds

Bowden, L. and Driscoll, P. (1997). 'Following the Flight of the Eastern Curlew'. Australian Marine Conservation Society Bulletin. Vol. 20, No. 1: 6-7.

Schodde, R. and Tidemann, S. C. (Eds). (1997). 'The Reader's Digest Complete Book of Australian Birds'. Reader's Digest Publ., Sydney.

Watkins, D. (1997). 'Maintaining Mudflats for the Migrants'. Australian Marine Conservation Society Bulletin. Vol. 20, No. 1: 6.

Wykes, B. and Bamford, M. (1990). 'Birdlife of South-west Estuaries'. Waterways Information No. 3, Waterways Commission (now Water and Rivers Commission), Perth.

Contacts

Government Agencies

Department of Conservation and Land Management, Telephone (08) 9334 0333.

Department of Environmental Protection, Tel. (08) 9222 7000.

Environment Australia, Community Information Unit, Canberra, Tel. (FREECALL) 1800 803 772.

Fisheries Western Australia, Tel. (08) 9482 7333.

Leschenault Inlet Management Authority, Bunbury, Telephone (08) 9721 1875.

Peel Inlet Management Authority, Mandurah, Tel. (08) 9535 3411.

Swan Catchment Centre, Tel. (08) 9221 3840.

Swan River Trust, Tel. (08) 9278 0400.

Water and Rivers Commission, Tel. (08) 9278 0300.

Wilson Inlet Management Authority, Denmark (WA), Telephone (08) 9848 1866.

Non-government Organisations

Australian Marine Conservation Society, (08) 9220 0679.

Birds Australia - WA Group, Tel. (08) 9383 7749.

Busselton-Dunsborough Environment Centre, Tel. (08) 9754 2049.

Coastal Waters Alliance of Western Australia, c/- B. Slight, Telephone (08) 9307 7290.

Coastcare, Telephone (08) 9264 7574.

Conservation Council of Western Australia, Tel. (08) 9220 0652.

Denmark Environment Centre, Tel. (08) 9848 1644.

Marine and Coastal Community Network, Tel. (08) 9220 0662.

Ribbons of Blue, c/- Water and Rivers Commission. Ten regional co-ordinators in the South-west.

South-West Environment Centre, Tel. (08) 9791 3210.

WA Gould League, Herdsman Lake Wildlife Centre, Tel. (08) 9387 6079.

Waterbird Conservation Group, c/- J. Payne, Tel. (08) 9371 1670.

Wetlands Conservation Society, c/- P. Jennings, Tel. (08) 9360 2274.

Glossary

Most of the following definitions have been adapted from 'Water Words. Water Facts No. 1 Information Sheet' (Water and Rivers Commission, Jan. 1998).

Algae

A diverse group of aquatic plants containing chlorophyll. Many are microscopic (often being single cells) but some can be large, including the large seaweeds. They grow as single cells (see Phytoplankton) or as an aggregation of cells (colonies).

Algal bloom

The rapid growth of algae, generally caused by high nutrient levels. Can result in the loss of oxygen in the water when the algae die, leading to the death of plants, fish and other aquatic fauna.

Biomass

The mass of living or dead matter present in an environment.

Blue green algae

Blue green algae are a sort of phytoplankton that has evolved from an ancient group of bacteria which produce their own energy from sunlight. A number of species produce toxins.

Brackish

See Salinity. Lower salt concentration than seawater, but greater than 500 ppm.

Catchment

An area of land which collects rainfall to streams, rivers, wetlands or groundwater.

Ecosystem

Term used to describe a specific environment and all the interconnections between its different parts, including animals, plants and micro-organisms.

Estuary

An enclosed or semi-enclosed coastal body of water having an open or intermittently open connection to marine waters and fresh input from land runoff.

Fertilisers

Chemicals or organic matter used to increase nutrients available to cultivated plants.

Habitat

Part of an ecosystem used by a species for its breeding, feeding and resting needs.

Macroinvertebrates

Macroinvertebrates are animals without a backbone, big enough to be seen with the human eye (though they can be very small). The main groups are worms, snails, crustaceans (e.g. prawns) and insects.

Micro-organism

An organism so small as to be invisible to the naked eye.

Nutrients

Minerals contained in various mediums (such as water, soil, and living and dead matter) that are used by plants and animals as food, or for their well being.

Pesticides

Chemicals used to control insects, fungi, weeds, algae, rodents that are damaging to human activities.

Phytoplankton

Microscopic aquatic plants (up to 1 to 2 mm in diameter).

Runoff

Water that flows over the ground surface from a catchment area into streams and other water bodies.

Salinity

The measure of salt constituents in water. Water is classified as fresh, brackish or saline according to the level of salinity (low, medium, high).

Sediment

Particles of mud or sand that accumulate at the bottom of water.

Acknowledgments

Primary sources of information for this material came from pamphlets by the Waterways Commission (1990), the Peel Preservation Group (1994) and the Water Facts information sheets produced by the Water and Rivers Commission.

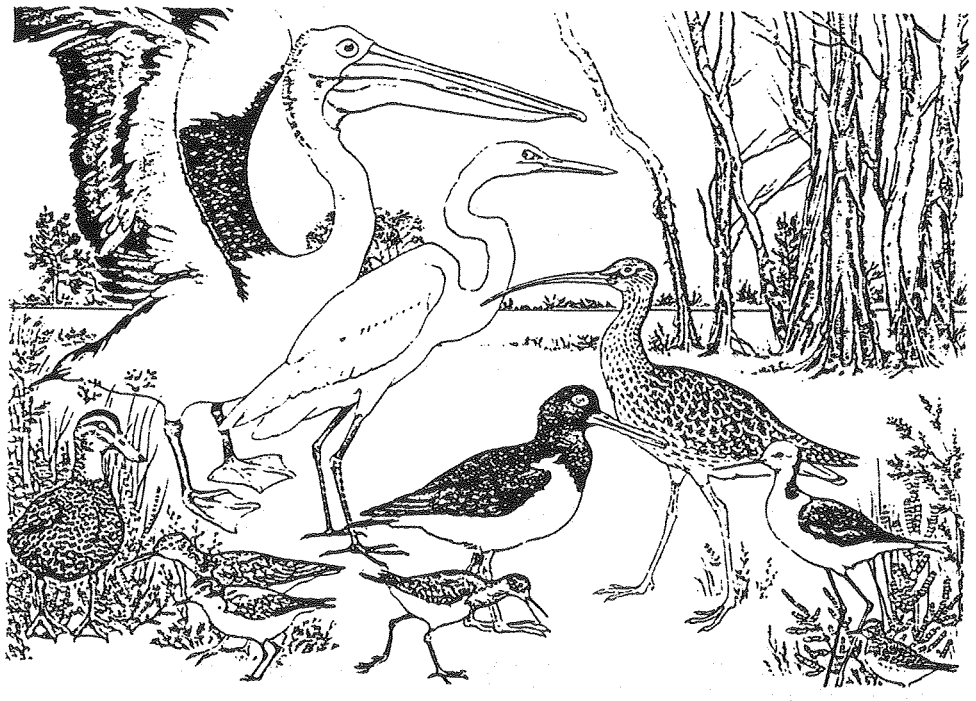


Figure 3. Birds commonly seen in estuaries.

Case Study 6
Seagrass Meadows: Supporting the Coastal Web of Life

What Is Biodiversity?

Biodiversity represents the sum of all living organisms, such as plants, animals and micro-organisms, their genetic variations and their interconnections within complex ecosystems.

Biodiversity exists everywhere: in forests, mountains, deserts, lakes, rivers and oceans. It is present in cities, houses and backyards, on farms and in any human modified environment, as well as around our bodies, on our skin and in our internal organs.

Biodiversity is the variety of life forms which exist on the Earth.

Biodiversity includes not only the plants and animals that we see around us (including ourselves), but also the myriad of microscopic organisms that inhabit our environment, such as fungi, algae, bacteria and viruses.

Most of the Earth's biodiversity consists of a large number of invertebrates, fungi, bacteria and non-flowering plants. Vertebrate animals and flowering plants represent only a small fraction of the total biodiversity, probably less than 1% in number of all species on Earth.

Seagrass Meadows: the Source of Life in Coastal Waters

Seagrass meadows and mangroves are the foundation of the ecological web of life in coastal marine areas. In Western Australia, where mangroves are only common from Shark Bay northwards, seagrasses play a major part in supporting the marine web of life. Seagrasses are not algae, like kelp, but are true flowering plants that live underwater. They get their energy from sunlight through photosynthesis like most algae and terrestrial plants.

Seagrasses are marine flowering plants.

Seagrass meadows provide food, shelter, and breeding and nursery grounds for many species of fish. In estuaries and coastal areas, seagrasses are important habitat for marine invertebrates, such as Blue Manna crabs, worms, molluscs and small crustaceans, which play an important role in food chains.

Seagrasses are important habitat and feeding grounds for marine organisms.

Seagrasses also shelter the larval stages of many fish and other sea creatures. Among the fish that live in seagrasses are leatherjackets, mullet and whiting, as well as juvenile Tailor, Buffalo Bream and flathead, and the elegant seadragons.

Many fish shelter in seagrasses.

Many seabirds, such as terns, Fairy Penguins and cormorants, and sea mammals, like sealions and dolphins, feed on fish. Thus, seagrasses may be important for the long term survival of these animals.

Without seagrasses many populations of fish and crustaceans would probably collapse. The loss of seagrasses in coastal sites may have far-reaching effects because juvenile fish, crabs and prawns need them as nursery grounds and for protection. Seagrasses are important not only for their role in maintaining biodiversity in the marine environment, but also for their value in supporting human activities such as commercial and recreational fishing.

Seagrasses are important nursery grounds for fish, and they support many human commercial activities.

Seagrasses
Australia has the highest diversity of seagrasses in the world, with 37 species.
Common names for seagrasses are eelweed, paddleweed, strapweed and ribbonweed.
The largest area of seagrasses in the world, the Wooramel seagrass bed, is found in Shark Bay, Western Australia. It covers 1000 km^2, has taken 5000 years to develop and supports over 10,000 dugongs. The Dugong is a sea mammal that feeds exclusively on seagrasses. It is endangered world-wide and is declining in Australia.
Much of the oxygen in the Earth's atmosphere is produced by phytoplankton in the ocean. Seagrasses also contribute to the oxygen produced by the ocean's plants.
Seagrasses produce pollen just like flowering plants on land. The pollen drifts in water currents until it meets another seagrass flower and pollinates it.

The largest seagrass beds in the world are found at Shark Bay.

The Seadragon's Tale

Seadragons are special fish which are found in seagrasses.

Of all the sea creatures living in seagrass meadows, seadragons help us best understand the reasons why seagrasses are so fragile. These remarkable fish are related to seahorses, but have developed seaweed-like extensions which provide a perfect camouflage against an underwater background of seaweeds and seagrasses.

There are two species of seadragons in the waters of South-western Australia: the Leafy Seadragon and the Weedy (or Common) Seadragon. The Leafy Seadragon has longer and wider extensions than the Weedy Seadragon and is rarer. Both species are found only in the waters of southern Australia. The Leafy Seadragon is fully protected in Western Australia.

There are two species of seadragons in the waters of southern WA.

Seadragons are part of the pipefish family, called Syngnathidae, which also include seahorses and pipefish. About 200 species of Syngnathidae exist world-wide. Seahorses have a unique characteristic: the female transfers the eggs into a special pouch-like fold on the male's abdomen. Attachments are formed between the egg and the abdominal wall of the male and nourishment is transmitted from the bloodstream of the parent. About 2 weeks after the eggs are laid there, the brood pouch of the male breaks, releasing the young into the water.

Seahorse males incubate eggs in their abdominal pouch.

The female seadragon transfers the eggs onto the underside of the male. Details about the reproductive biology of the seadragon are not clear, but a similar link may exist between the eggs and the bloodstream of the male. Young seadragon hatch and are released in the water where they start feeding almost immediately on tiny organisms.

Male seadragons may be able to supply nourishment to developing eggs.

Seadragons feed on shrimp and other minute crustaceans which they find in seagrass meadows and kelp forests (kelp is a giant seaweed that grows on the south coast of Australia).

Seadragons feed on crustaceans.

Researchers at Underwater World (Hillarys, Perth) have made advances towards unravelling the life history of seadragons, as young have been born there from a male which already had eggs in its pouch and observations could easily be made.

Seadragons are threatened because of collection for the aquarium trade, and also because of damage to seagrass beds and ever-diminishing area of habitat

Seadragons are becoming rarer due to ever-diminishing habitat.

Figure 1. Seagrasses in the Web of Life.

Human Impacts: Seagrasses in Crisis

In recent years, seagrasses have suffered a great decline around Australia. The loss of seagrass beds is one of the major issues affecting Australia's marine environment (see Figure 2). The State of the Environment Report 1996 for Australia states (Chapter 10, page 20):

Seagrass meadow areas are on the decline around Australia.

"A particularly serious problem appears to be the loss of seagrass beds, with more than 1600 km^2 (about three per cent of the total known area of Australian seagrass) lost in recent decades around the coast.

Some of the loss of seagrass meadows is due to human activities.

Much of this loss is attributed to floods and cyclones, with the remainder due to human changes such as increased nutrient levels, runoff, water muddiness, dredging and reclamation.

Prospects for recovery are poor as there are very few records of temperate seagrass recovering from damage or loss.

Seagrass beds are critical habitats for turtles and dugong, as well as being important nursery areas for commercial and recreational fisheries. Their loss must cause concern, especially as the temperate seagrass areas may not respond successfully to changes in climate."

Turtles and dugongs depend on seagrasses for their survival

Reasons for Seagrass Loss

There are many causes for the loss of seagrasses around Australia. Some of these relate to what happens on land, even in areas which are a long way from the coast, while others causes are linked to problems in the sea.

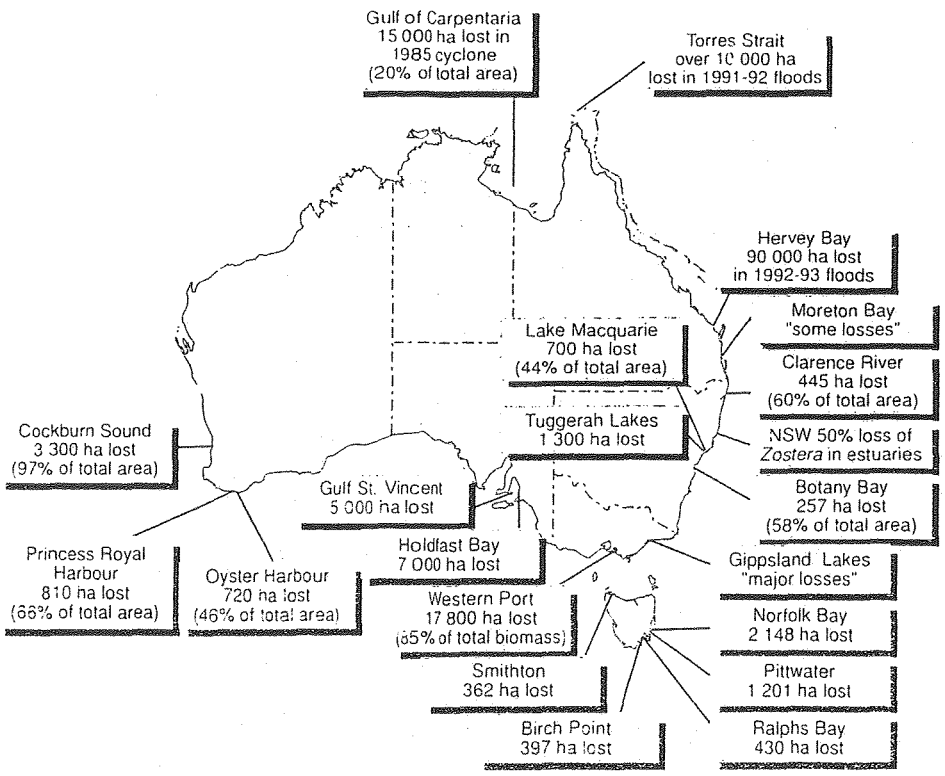


Figure 2. The major areas of seagrass loss in Australia. (Source: "Our Sea, Our Future?" State of the Marine Environment Report, 1995).

Water Muddiness

Healthy vegetation reduces erosion and runoff when it rains. Land clearing, overgrazing, mining, logging and frequent burning, however, reduce vegetation cover and cause erosion. Rivers carry sand or mud particles to the sea, damaging seagrass beds. The impact of floods is greatly increased by clearing of catchments for agriculture and urban development, which increases the speed and volume of rivers flowing into the ocean.

Sediments from land erosion are continually flowing into the ocean.

Excess sediments in the sea kill seagrasses by reducing the amount of light reaching the plants and smothering their leaf blades, thus reducing the ability of the plants to receive light and to grow. Water muddiness can be caused by sand and mud particles being carried by rivers into the ocean, by dredging, and the action of ships, small boats and jet skis. Cyclones and floods can cause great damage to seagrass beds by burying them under sand and mud.

Excess sediments reduce light penetration in the water.

Pollution and Excess Nutrients

Pollution comes from industrial areas and from pesticides and other chemicals used in agriculture. Excess nutrients usually come from agricultural land (runoff of fertilisers and livestock waste products), from urban sewage as well as polluted runoff from roads and suburban backyards.

Pollution and excess nutrients are causing the decline of seagrasses.

Pollution and excess nutrients in the sea lead to the decline of seagrasses. Excess nutrients in the water cause algal growth on the leaves of seagrasses. This restricts the amount of light seagrasses receive and they eventually die. Large areas of seagrasses have been lost in Oyster Harbour and

Large areas of seagrass beds have been lost in the Southwest.

Princess Royal Harbour near Albany due to the build-up of nutrients from sewage outfalls and agricultural wastes. Limited regrowth has occurred over the last few years and may indicate a recent improvement of water quality in these harbours.

Impact of Boating

Anchors can inflict severe damage to seagrass beds, ripping out large clumps of seagrasses. Moorings often cause large holes in seagrass beds as the chain drags across the bottom when the boats swing around. In shallow areas, boat propellers and jetskis can open a cut through a seagrass bed that takes years to regrow.

Boats and moorings are further reducing seagrass meadows.

Decline of Seagrasses: the Example of Cockburn Sound

The location of the Kwinana heavy industry area on the shores of Cockburn Sound led to the loss of up to 97% of seagrass beds in the Sound by 1978: "... industrial discharges into Cockburn Sound in Western Australia have been associated with massive loss of seagrasses and substantial levels of contamination of sediments and fish" ('Australia: State of the Environment 1996', Chapter 8, page 25).

Industrial discharge can kill seagrasses.

Whereas in the 1970s most of the pollution in Cockburn Sound came directly from the Kwinana industrial area, now 70% of the pollution that is leached into the ocean comes from the contaminated groundwater table and sediments that have stored high levels of nutrients. The amount of pollution is now returning to the worst known levels of 25 years ago. A new deep water port the size of Fremantle is planned in Jervoise Bay and is likely to increase the environmental pressures on the Sound.

Dredging for lime sands is a major threat to seagrass beds. In Success Bank, just outside Cockburn Sound, ongoing lime sand extraction is threatening seagrass meadows by increasing both turbidity and seagrass removal.

Dredging for lime sand is threatening seagrass meadows.

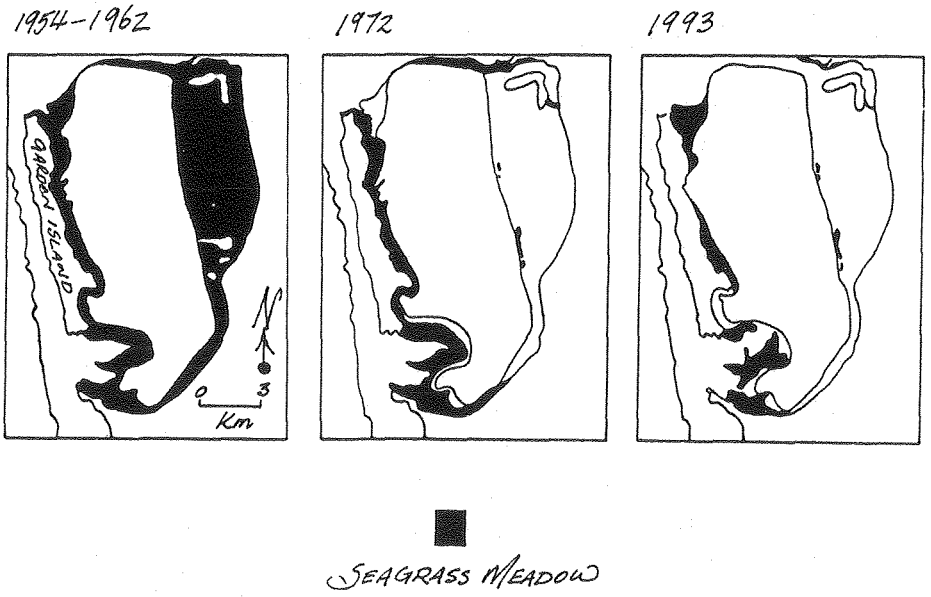


Figure 3. Seagrass cover and loss in Cockburn Sound 1954-93. (Source: South Metropolitan Waters Study, Dept Environmental Protection 1996).

There is no simple way of restoring seagrass beds once they have been destroyed. Seagrasses are slow-growing and it is not known how long natural regeneration will take. Experiments to replant seagrasses after dredging have shown that small seagrass clumps can be grown. However, there is no indication that seagrasses can be grown over large areas.

Seagrass meadows are slow to recover and re-grow.

Seagrasses: Our Best Ally to Protect the Coast

Protection of the Coastline from Storm Damage

Seagrass beds help protect the coastline from storm damage and are nature's engineering solution to the impact of erosion caused by the force of water on the coastline. Seagrasses play an important role in trapping and stabilising sand and sediments that drift along the coast by slowing down the flow of water and reducing the action of swells and waves on the coastline.

Seagrasses moderate water flow along the coastline.

Value of Coastal Areas

Humans are constant users of the coast and coastal waters. These uses include amateur and commercial fishing, tourism, and industrial and urban development. Leisure activities, such as boating and family outings to the local beach, are an important part of the Australian way of life. Without a healthy environment and adequate environmental protection, many of these uses may soon no longer be possible or viable.

What We Can Do

Protection of seagrasses can be achieved by making it illegal to damage or kill seagrasses, by giving incentives to improve land conservation practices in agricultural catchments, by increasing awareness about the need to conserve seagrasses, and by encouraging boat owners not to drop anchors in seagrass beds or damage seagrasses with boat propellers or jet skis. Moorings can be redesigned to have a chain that does not drag on the ocean floor.

We must start to protect our seagrass meadows from damage and destruction.

The Marine and Coastal Community Network or Australian Marine Conservation Society can organise a talk at your school or let you know which activities are taking place on the coast. Many activities take place on Ocean Care Day on the first Sunday of December, or during SeaWeek in March each year.

Suggested Activities

Super Seagrass Marketing Campaign

The *Super Seagrass Saviours* is a company that has been set up to inform Western Australians about the value of Seagrass in the Coastal Web of Life. Students in your class have been selected to create the campaign.

Divide the class into workgroups who are each responsible for the creation of a marketing campaign that includes a brochure, advertising poster and information booklet about the contribution to biodiversity made by Seagrass.

The campaign should be presented as part of an oral presentation to the rest of the class *or* a panel of peers (if this is not possible, then teachers or

visitors) who will act as the *Super Seagrass Saviours Pty. Ltd.* (This provides an opportunity for peer evaluation and immediate constructive feedback).

Seagrass Mural

Invite students to suggest a series of outcomes if all grass were removed from the land and consider the impact of that on their lives.

Once the discussion has been exhausted, introduce the "term" seagrass and invite students to consider where it might be found and what its role might be in the sea environment.

Use this discussion to lead into the information about the seagrass contained in the biodiversity package.

After reading the information, each student to take one species from the seagrass meadow (use species list contained in package) and research it.

As a class, create a large mural that shows the biodiversity of the seagrass meadow. Once the mural is completed, the class can use it as a basis to discuss the reasons for Seagrass loss and create ways to add these reasons to the mural. Consider the possibility of destroying parts of the mural in the process and enable students to explore their reactions to this - link this to the destruction of the seagrass environment.

Discuss ways in which the students can utilise their energy and reactions to help save the seagrass.

Application to the Student Outcome Statements

Arts - Using arts skills, techniques, technologies and processes; Communicating Arts Ideas.

English - Speaking and Listening (Use of Texts, Contextual Understanding, Conventions, Processes and Strategies); Reading (Use of Texts, Contextual Understanding, Conventions, Processes and Strategies); Writing (Use of Texts, Contextual Understanding, Conventions, Processes and Strategies).

Extension Activities for Students

Science, and Society and Environment

1. For each map of seagrass meadows in Cockburn Sound in 1954–62, 1972 and 1993 (Figure 3), measure the area of seagrasses and place these values on a graph with time on the X (horizontal) axis and seagrass area on the Y (vertical) axis.

   Calculate the percentage of decrease in seagrass area between 1954–62 and 1972, and between 1954-62 and 1993. What will happen to seagrasses in Cockburn Sound if the same trend continues?
2. Draw a food web of the different types of animals that inhabit seagrasses and other coastal habitats, from crabs and prawns to sealions, dolphins and sea birds. Keep in mind the ratio of each species which should exist. For example, animals on the top of the food web are fewer in number than seagrasses and crustaceans at the bottom end.

3. Seagrasses use the sun's energy for their growth. This process is called photosynthesis. Carbon dioxide from the air (but dissolved in water) and other chemicals in the water are used by the plant and changed into oxygen and food.
   Using Figure 1, describe what happens if the sea water contains too many particles of mud and silt. What happens when the sea water contains too many nutrients and there is an increase of algae on the leaf blades of seagrasses?
4. Draw an explosion chart or mind map to show ways to protect seagrasses along the coast nearest to where you live.
   Identify the threats to their survival and what could be done to remedy these problems.

The Arts and English

Drama: write and act out a play based on the life story of the Seadragon including as many species as possible that rely on seagrasses for their living (don't forget humans).

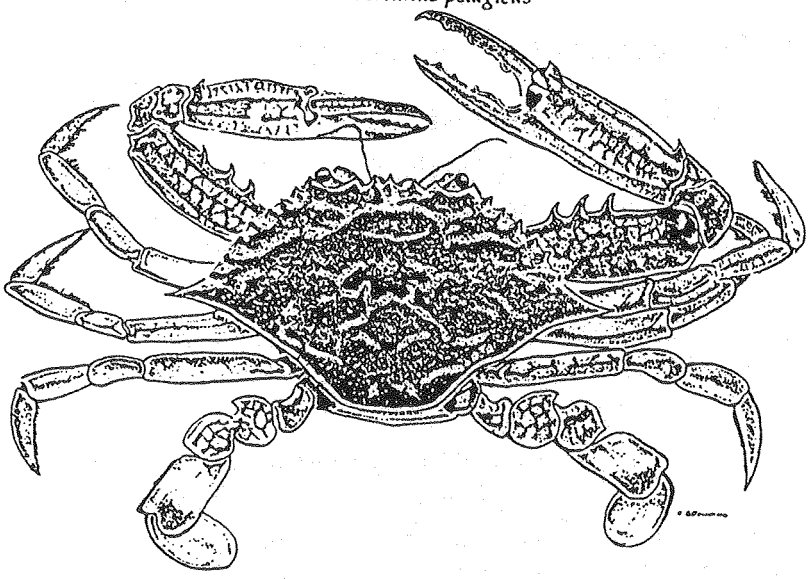
Use puppets and costumes to act out the story.

Art: create a composition of the underwater world in a seagrass meadow.

Field Studies

1. Visit your local beach and look for washed-up seagrasses.
   Note the different types of seagrasses present. How do you think they have arrived there?
2. Go snorkelling and observe life in a seagrass meadow.
   For information on where to go, call the Australian Marine Conservation Society or the Education Unit at CALM, Fremantle.
3. Join the National Dragon Search project by calling the project coordinator on (08) 9220 0679.
4. Organise a visit to Underwater World with your class.

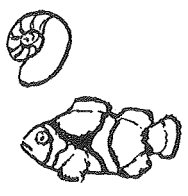
Portunus pelagicus

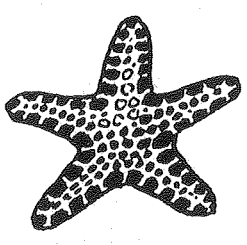


Species List

List of the species connected to seagrasses with their common and scientific names.

Type of organism	Common name	Scientific name
Seagrasses		
	Eelgrass	*Zostera* spp.
	Paddle Weed	*Halophila ovalis*
	Ribbon Weed	*Posidonia australis*, *P. sinuosa*
	Strapweed	*Amphibolis antartica*, *A. griffithii*
Crustaceans		
	Blue Manna Crab	*Portunus pelagicus*
	Western King Prawn	*Penaeus latisulcatus*
	Swan River Prawn	*Metapenaeus dalli*
	Crayfish or Western Rock Lobster	*Panulirus cygnus*
Fish		
	Leafy Seadragon	*Phycodurus eques*
	Weedy Seadragon	*Phyllopteryx taeniolatus*
	Seahorses	*Hippocampus* spp.
	Buffalo Bream	*Kyphosus cornelii*
	Flathead	*Platycephalus* spp.
	Mullet	*Liza* spp., *Myxus elongatus*, *Mugil cephalus*
	Tailor	*Pomatomus saltatrix*
	Whiting	*Sillago* spp.
Mammals		
	Australian Sealion	*Neophoca cinerea*
	Bottlenose Dolphin	*Tursiops truncatus*
	Dugong	*Dugong dugon*
Birds		
	Fairy Penguin	*Eudyptula minor*
	Cormorants	*Phalacrocorax* spp.
	Terns	*Sterna* spp.





Specific Websites

Marine Information Sites

Australian Marine Conservation Society website:
http://www.ozemail.com.au/~amcs/

Marine and Coastal Community Network website:
http://www.ozemail.com.au/~mccnet/

ABC's oceans website: http://www.abc.net.au/oceans/alive.htm

Marine studies textbook: http://www.wetpaper.com.au/

Seadragon Sites

Dragon Search home page: http://www.dragonsearch.asn.au

Dragon Search home page (Marine and Coastal Community Network-South Australia):
http://www.nexus.edu.au/schools/kingscot/pelican/Seadragon/Sd_index.htm

Underwater World Seadragon page (Singapore):
http://www.underwaterworld.com.sg/seadrago.htm

Underwater World (Hillarys, Perth) Seadragon page:
http://coralworld.com/perth/gallery/seadragons/

Further Reading

General

AMCS. (1997). 'How to Save our Coast and Oceans'. Coastal Community Resource Kit. Australian Marine Conservation Society, Perth.

ASTA. (1998). 'Exploring Oceans'. A Resource Book of Activities and Information for National Science Week. Australian Science Teachers Association, Deakin, ACT.

Dakin, W.J. (1987). 'Australian Seashores'. Angus and Robertson, Sydney.

DEP. (1996). 'South Metropolitan Coastal Waters Study (1991–1994)'. Summary Report. Department of Environmental Protection, Perth.

Environment Australia. (1996). 'Australia: State of the Environment 1996'. CSIRO Publishing, Collingwood, Victoria. Also on CD-ROM available from Environment Australia, Community Information Unit, Tel. (FREECALL) 1800 803 772.

Zann, L. (1995). 'Our sea, Our Future'. State of the Marine Environment Report for Australia. Department of Environment, Sport and Territories, Canberra. Available from Environment Australia, Community Information Unit, Tel. (FREECALL) 1800 803 772.

On Seadragons and Seahorses

Kuiter, R. H. (1988). 'The Birth of a Leafy Seadragon'. Australian Geographic No. 12.

McDonald, K. (1998). 'Seadragons: Icons of the Deep'. Earth 2000. The West Australian, 9 Feb.

National Dragon Search Project. 'The Dragon's Lair' newsletter (twice a year). See Dragon Search website.

'Seahorses' (1994). Australian Geographic No. 33.

On Seagrasses

Open Channel. (1989). 'The Seagrass Story - Seagrass Event '89'. Video in association with the Westernport Peninsula Protection Council and Ian Cumming (30 min). Available from Community Arts Network (WA), Tel. (08) 9226 2422.

Walker, D. (1992). 'Grasses of the Sea'. Landscope, Summer 1991/92: 42-46.

Contacts

Australian Marine Conservation Society (WA), Tel. (08) 9220 0679.

Coastal Waters Alliance of Western Australia, C/- Bob Slight, Tel. (08) 9307 7290.

Department of Conservation and Land Management, Marine Conservation Branch, Tel. (08) 9432 5100.

Edith Cowan University, Department of Environmental Management, Tel. (08) 9400 5189.

Fisheries Western Australia, Tel. (08) 9482 7333.

Marine and Coastal Community Network, Tel. (08) 9220 0662.

Murdoch University, Dr Eric Paling, Tel. (08) 9360 6121.

Coasts and Clean Seas program, Environment Australia, Tel. (FREECALL) 1800 803 772.

Underwater World, Hillarys, Tel. (08) 9447 7500.

University of Western Australia, Department of Botany, Telephone (08) 9380 2089.

WA Gould League, Herdsman Lake Wildlife Centre, Tel. (08) 9387 6079.

Water and Rivers Commission, Tel. (08) 9278 0300.

Glossary

The following definitions have been taken from *Water Words*. Water Facts No. 1 information sheet (Water and Rivers Commission, Jan. 1998).

Algae

A diverse group of aquatic plants containing chlorophyll. Many are microscopic (often being single cells) but some can be large, including the large seaweeds. They grow as single cells or an aggregation of cells (colonies). Phytoplankton is one type of microalgae.

Ecosystem

Term used to describe the web of life within a community and its specific environment, such as lake, mountain, coast, forest.

Habitat

Part of an ecosystem used by a species for its breeding, feeding and resting needs.

Invertebrate

Animal without a backbone.

Nutrients
Minerals dissolved in water, particularly nitrates, ammonia and phosphates which provide food for plant growth.

Nutrient enrichment
Excessive enrichment of water by dissolved nutrients, particularly nitrates and phosphates, which lead to excessive growth of aquatic plants.

Phytoplankton (see Algae)

Photosynthesis
Use of sunlight energy by plants to transform carbon dioxide and water into sugars and other complex organic substances.

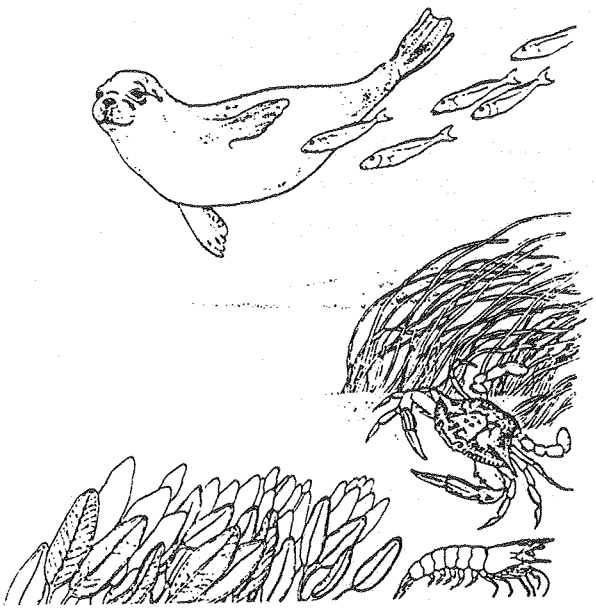
Reclamation
Filling coastal areas with rocks and soil to create new land.

Runoff
Water that flows over the surface from a catchment area into streams and other water bodies.

Seagrass
Marine flowering plant adapted to living wholly submerged in seawater. They are not true grasses, but many have a grass-like form.

Sediment
Particles of mud or sand that accumulate on the bottom of a water body.

Water Pollution
Water pollution occurs when waste products such as effluent, rubbish, noxious chemicals, sewage or contaminated runoff, change the quality of the water.



Appendix: Additional Education Resources on Biodiversity

A range of resources is available on Australian biodiversity for school students, teachers and educators. Included here are additional references and websites, and links to the Student Outcome Statements produced by the Education Department of Western Australia in 1998.

Additional References

Publications Available on Request

All the following publications can be obtained free of charge from the Community Information Unit, Environment Australia, Tel. 1800 803 772 (FREECALL). They are also available on-line from the Environment Australia website: http://www.environment.gov.au/portfolio/esd/biodiv/what_is.html.

Biodiversity Series Papers

Glanznig, A. (1995). 'Native Vegetation Clearance, Habitat Loss and Biodiversity Decline'. Biodiversity Series Paper No. 6.

Graetz, R. D., Wilson, M. A. and Campbell, S. K. (1995). 'Landcover Disturbance over the Australian Continent, a Contemporary Assessment'. Biodiversity Series Paper No. 7.

Preece, N., van Osterzee, P. and James, D. (1995). 'Two Way Track: Biodiversity Conservation and Ecotourism'. Biodiversity Series Paper 5.

'Biodiversity and Fire: the Effects and Effectiveness of Fire Management'. Biodiversity Series Paper No. 8 (1996).

Strategies and Policies (Commonwealth Government)

'Australia's National Strategy for Ecologically Sustainable Development' (1992).

'An Australian National Strategy for the Conservation of Species and Communities Threatened with Extinction' (1992). Available on:
http://www.anca. gov.au/plants/threaten.

'Australia's Oceans Policy' (1998). Biodiversity Conservation. Issues paper No. 7.

Newsletters

The newsletters below are available from Environment Australia:

'On the Brink', newsletter of the Threatened Species and Communities program.

'Wetlands Australia', newsletter of the National Wetlands Program.

'Flightlines', newsletter of the Australian Bird and Bat Banding Scheme.

The following newsletters are available from each organisation's website or as a hard copy:

'Life Lines', Bulletin of the Community Biodiversity Network.

'The Greener Times', newsletter of the Conservation Council of Western Australia.

'Waves', newsletter of the Marine and Coastal Community Network.

'The Dragon's Lair', newsletter of the Dragon Search Project.

Other Publications

Australian Association for Environmental Education

The series 'Case Studies in Biodiversity and Ecologically Sustainable Development' was produced by the Australian Association for Environmental Education for the National Professional Development Program and includes the following publications:

Allen, T. *et al.* (Eds). (1996). 'Southern Temperate Australia'.

Michie, M. (1995). 'Study Guide'. Northern Territory University, Darwin.

Michie, M. *et al.* (Eds). (1995). 'Readings'.

References Related to Various Sections of the Package

General Introduction

'A Nature Conservation Strategy for Western Australia' (1992). A draft for public comment. Department of Conservation and Land Management, Como.

'Outcomes and Standards Framework', Education Department of Western Australia (1998).

Carnaby's Cockatoo

Garnett, S. (1992). Threatened and extinct birds of Australia. Royal Australasian Ornithologists Union, Report No. 82, Victoria.

Lamont, B. B. (1994). Triangular trophic relationships in Mediterranean climate Western Australia. In: Arianoutsou, M. and Groves, R. H. (Eds). 'Plant-Animal Interactions in Mediterranean-Type Ecosystems'. pp. 83-89. Kluwer Acad. Publ., Netherlands.

Saunders, D. A. and Curry, P. J. (1990). The impact of agricultural and pastoral industries on birds in the southern half of Western Australia - past, present and future. In: Saunders, D. A. et al. (Eds). 'Australian ecosystems: 200 Years of utilisation, degradation and reconstruction'. Proceedings of the Ecological Society of Australia 16: 303-21.

Saunders, D.A. and de Rebeira, C. P. (1991). Values of corridors to avian populations in a fragmented landscape. In: Saunders, D.A. and Hobbs, R. J. (Eds). 'Nature Conservation 2. The Role of Corridors', pp. 221–40. Surrey Beatty and Sons: Chipping Norton, NSW.

Serventy, D. L. and Whittell, H. M. (1976). Birds of Western Australia. University of Western Australia Press, Perth.

Honey Possum

Pate, J. S. and Beard, J. S. (Eds). (1984). Kwongan - Plant Life in the Sandplain. University of Western Australia Press, Nedlands.

Renfree, M. B., Russell, E. M. and Wooller, R. D. (1984). Reproduction and Life History of the Honey possum, *Tarsipes rostratus*. In: Smith, A. P. and Hume, I. D. (Eds). 'Possums and Gliders'. pp. 427-37. Australian Mammal Society, Sydney. Surrey Beatty and Sons, Chipping Norton.

Wills, R. T. and Keighery, G. J. (1994). Ecological impact of plant disease on plant communities. In: Withers et al. (Eds). 'Plant diseases in ecosystems: threats and impacts in south-western Australia'. Journal of the Royal Society of Western Australia 77 (4): 127-132.

Wooller, R. D., Russell, E. M. and Renfree, M. B. (1984). Honey Possums and their food plants. In: Smith, A. P. and Hume, I. D. (Eds). 'Possums and Gliders'. pp. 439-43. Australian Mammal Society, Sydney. Surrey Beatty and Sons, Chipping Norton.

Wooller, R. D., Russell, E. M., Renfree, M. B. and Towers, P. A. (1983). Comparison of seasonal changes in the pollen loads of nectarivorous marsupials and birds. *Australian Wildlife Research* 10:311-317.

Mistletoebird

Common, I. F. B. and Waterhouse, D. F. (1981). Butterflies of Australia. Angus and Robertson, Sydney.

Lamont, B. (1992). Functional interactions within plants - the contribution of keystone and other species to biological diversity. In: Hobbs, R. J. (Ed). 'Biodiversity of Mediterranean Ecosystems in Australia'. pp. 95-127. Surrey Beatty and Sons, Sydney.

Main, A. R. (1992). The role of diversity in ecosystem function: an overview. In: Hobbs, R. J. (Ed). 'Biodiversity of Mediterranean Ecosystems in Australia'. Surrey Beatty and Sons, Sydney.

Woylie

Christensen, P. E. S. (1980). The biology of *Bettongia penicillata* (Gray, 1837) and *Macropus eugenii* (Desmaret, 1817) in relation to fire. Forest Dept of Western Australia. Bulletin 91.

Lamont, B. B. (1994). Triangular trophic relationships in Mediterranean climate Western Australia. In: Arianoutsou, M. and Groves, R. H. (Eds). 'Plant-Animal Interactions in Mediterranean-Type Ecosystems'. pp. 83-89. Kluwer Acad. Publ., Netherlands.

Lamont, B. B. (1995). Interdependence of woody plants, higher fungi and small marsupials in the context of fire. CALM Science Supplement 4: 151-158.

Additional Contacts and Websites

Government Agencies, Research and Academic Organisations

Western Australia

CSIRO, Division of Wildlife and Ecology, Underwood Avenue, Floreat WA 6014. Tel. (08) 9333 6200. Website: http://www.csiro.au/

Curtin University, School of Environmental Biology, GPO Box U1987, Perth WA 6001. Tel. (08) 9266 7368. Website: http://www.curtin.edu.au/

Education Department of Western Australia, 151 Royal Street, East Perth WA 6004. Tel. (08) 92644944. Website: http://www.eddept.wa.edu.au/

Edith Cowan University, School of Natural Sciences, Centre for Ecosystem Management, Joondalup Campus, 100 Joondalup Drive, Joondalup WA 6027. Tel. (08) 9400 5651. Website: http://www.cowan.edu.au/

Murdoch University, School of Biological Sciences, Murdoch Drive, Murdoch WA 6150. Tel. (08) 9360 6265.
Website: http://wwwscience.murdoch. edu.au/conbiol/

Swan Catchment Centre, 108 Adelaide Terrace, Perth WA 6000. Tel. (08) 9221 3840.

University of Western Australia, Department of Zoology, Nedlands WA 6009. Tel. (08) 9380 2227. Website: http://www.uwa.edu.au/

Western Australian Herbarium, George Street, South Perth WA 6151. Tel. (08) 9334 0500.

Interstate

Australian Museum, 6 College Street, Sydney NSW 2000. Tel. (02) 9320 6348. Website: http://www.austmus.gov.au/

Charles Sturt University, School of Environmental and Information Sciences, PO Box 789, Albury , NSW 2640. Tel. (02) 6051 9730. Website: http://www.csu.edu.au/

Macquarie University, Key Centre for Biodiversity and Bioresources, School of Biological Sciences, Sydney NSW 2109. Tel. (02) 9850 8153. Website: http://www.bio.mq.edu.au/

Non-government Organisations

Western Australia

Birds Australia - WA Group, 71 Oceanic Drive, Floreat WA 6014. Tel. (08) 9383 7749. Website: http://avoca.vicnet.net.au/~birdsaus/

Environment Centre of Western Australia, Westminster House, 1st Floor, 10 Pier Street, Perth WA 6850. Tel. (08) 9225 4103. Website: http://www. iinet.net.au/~ecwa/

Greenteach, c/- Ross Mars, John Forrest SHS, Drake St, Embleton WA 6062. Tel. (08) 9272 1255.

National Biodiversity Council (WA chapter), c/- Prof. Harry Recher and Dr Pierre Horwitz, Edith Cowan University, School of Environmental Management, Joondalup Campus. Tel. (08) 9400 5189.

Western Australian Naturalists' Club, PO Box 156, Nedlands WA 6009. c/- G. Elliott, Tel. (08) 9272 1674.

Wilderness Society, 79 Stirling Street, Perth WA 6000. Tel. (08) 9228 2811. Website: http://www.green.net.au/twswa/

Wildflower Society of Western Australia, 71 Oceanic Drive, Floreat WA 6014. Tel. (08) 9383 7979.
Website: http://www.ozemail.com.au/~wildflowers/

More Biodiversity Websites

Organisation Websites

Environment Australia, Canberra: http://www.environment.gov.au/

Environmental Resources Information Network (Environment Australia): http://www.environment.gov.au/life/life.html

Australian Environmental Education Network (Environment Australia): http://www.environment.gov.au/net/aeen.html

Charles Sturt University, NSW: http://www.csu.edu.au/biodiversity.html

UNESCO's environmental education site: http://unesco.uneb.edu/educprog/ste/

Rice University, Houston, USA: http://conbio.rice.edu/

Interstate

Australian Conservation Foundation, 340 Gore Street, Fitzroy Vic 3065. Tel. (FREECALL) 1800 332 510. Website: http://www.acfonline.org.au

Greenpeace, PO Box 6307, 39 Liverpool Street, Sydney NSW 2000. Tel. (FREECALL) 1800 815 151. Website: http://www.greenpeace.org.au/

Humane Society International, GPO Box 439, Avalon NSW 2107. Tel. (02) 9973 1728.

Student Outcome Statements

This education resource is primarily relevant to the following Learning Areas: Science, Society and Environment, English and The Arts. Within each Learning Area, the following relevant strands have been identified. These are shown in the table below.

Learning Area	Strand
Science	Life and Living Investigating Scientifically
Society and Environment	Investigation, Communication and Participation Place and Space Resources Culture Time, Continuity and Change Natural and Social Systems Active Citizenship
The Arts	Communicating Arts ideas Learning Arts skills Evaluating The Arts Understanding the Role of The Arts in Society
English	Speaking and Listening Viewing Reading Writing

The Strand Outcome Statements can be obtained from the website:
http://www.eddept.wa.edu.au/centoff/outcomes/science/scmenu.htm