Protecting Earth's life-suppor

What is biodiversity?

Biological diversity (or biodiversity) is the variety of life: the different plants, animals and microorganisms, the genes they contain and the ecosystem of which they form a part. The concept is often considered at genetic, species and ecosystem levels.

Genetic diversity is the heritable variation which occurs within species populations. Essentially, it is the result of the different forms in which genes can occur. Genes are biochemical packages (DNA) which are passed on by parents and determine the physical and biochemical characteristics of their offspring.

Sometimes genetic diversity can be seen. For example, there are obvious differences among regional populations of the Australian white-cheeked rosella, which are all different forms of the same species. In other cases the genetic variation is invisible, but still there. For example, a species of native flax (*Linum marginale*), which is a wild relative of the linseed crop plant, is attacked by rust fungus. Natural populations of flax contain individuals that are genetically immune to the rust, yet their genetic immunity only becomes apparent when a population of the flax is infected.

Species diversity is the number of different species (also known as species richness). A species is a group of organisms genetically so similar that they can interbreed and produce fertile offspring. It is not just the number of species in an area that is important, but also the relative numbers of individuals per species. While there is no certainty about numbers, there could be as many as 10 to 30 million species on Earth (excluding bacteria).

Ecosystem diversity is the variety of habitats, communities and ecological processes in the biosphere. An ecosystem consists of communities of plants and animals and the non-living parts of their environment (such as soil, water and air). The biosphere is the region of the Earth's crust and atmosphere in which living organisms are found.

Bryony Bennett

Biodiversity is emerging as the central concept of conservation strategies worldwide. Here are some of the reasons why.

Conserving biological diversity is the key to ecologically-sustainable development and essential to maintaining the basic processes on which human life depends.

Biodiversity provides us with fresh air and water, food, medicines and industrial products. It offers recreational opportunities and is a source of inspiration and cultural identity.

Biological systems, through species metabolism and interaction, take non-living components of the environment, such as the sun's radiation, soil, air and water, and convert them into forms of energy and nutrients that we can use. Ecosystem functions include gas exchange, decomposition, nutrient cycling, energy transfer, herbivory, pollination and seed dispersal. These processes support human life by maintaining 'services' such as air and water quality, waste disposal, soil fertility and pest and disease control, in addition to all our food needs.

Australia's mallee moths, of which there are 6000 species, are an example of our indirect dependence on biological diversity. Mallee moths are the principal feeders on dead eucalypt leaves, which they break down for incorporation in the soil, improving its quality.

A decline in mallee moth numbers can lead to a significant drop in the productivity of natural and agricultural ecosystems. So can the reduction of termites, spiders, fungi, ants, plants and many other native species.

Scientists are often asked how much biological diversity is necessary, and how many species we can safely afford to lose. One answer is to draw an analogy with the airworthiness of an aircraft.

Imagine walking towards an aircraft, ready to depart on a journey, and seeing a mechanic on the wing, popping out rivets (which have been shown to have a useful re-sale value). How many rivets would you be prepared to see removed from the wing before you refused to fly?

This analogy is made on the basis that the plane is manufactured with more rivets than are necessary to fly safely. Presumably the aircraft's designers would know how many rivets are needed because they planned the system to begin with.

Biodiversity on the other hand doesn't come with a detailed blueprint. We don't know how many species there are on Earth, or much about the distribution, ecology and dynamics of all but a few species.

Little scientific evidence exists to suggest that biodiversity is important in maintaining functioning ecosystems, mainly because studies have rarely been designed to test this hypothesis. Scientists are now being challenged to develop techniques for measuring (or estimating) biodiversity, for assessing its role in ecosystem processes and for managing natural resources in a way that is ecologically sustainable.

Keeping a healthy economy

Our economy is also based on biological diversity. Biodiversity supports harvesting industries such as forestry and fisheries, and agriculture depends on soil microbes and ecological processes as well as plants and animals.

Many species are valuable to the pharmaceutical industry. The World Health Organisation estimates that 80% of the people in developing countries rely on traditional medicine for their primary health care needs. About 85% of this medicine involves the use of plant extracts. Approximately 120 pure chemical substances are used in modern medicines throughout the world. About 74% of these have the same or related use in traditional medicine. Given the extensive knowledge and use of Australian plants for medicinal uses by Aborigines, who knows what life-saving products might be produced?

Genetic as well as species diversity can bring economic benefit. Our native plants contain genetic information that

Great Barrier Reef Marine Park Authority

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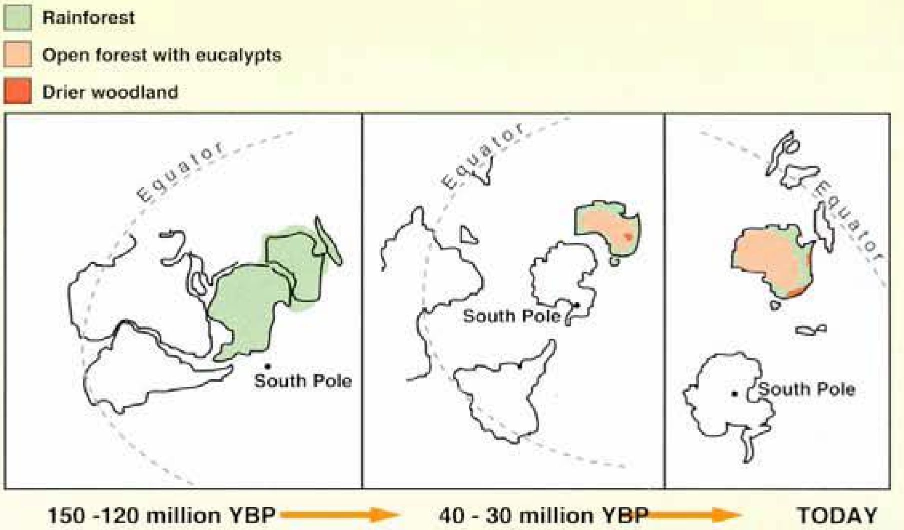

Australia, isolated from the rest of the world for more than 50 million years, is characterised by its unique plants and animals. (YBP-years before present.)

can be incorporated into crop plants to make them more hardy or resistant to disease. Northern Territory's floral emblem, the desert rose, shows potential for crossbreeding with commercial cotton varieties to produce a crop plant better suited to Australian climatic conditions. Native flax species genetically immune to rust disease can be bred with commercial linseed genotypes to provide rust resistance.

Some of the rust resistance genes enabling Australia to have a cereal production industry have come from wild grass species that grow in Turkey, Israel and other Mediterranean countries. Australian agricultural and horticultural production depends on genes from around the world and the potential use of genes contained in our own unique flora is just beginning to be realised.

In future scientists will be more skilled at recognising and using this wealth to make the dramatic changes that will be needed in our agriculture, not only to produce food, but to create a sustainable base for the raw materials of industry and medicine.

The conservation of Australia's biodiversity has cultural importance too. Many Australians place a high value on native plants, animals and their habitats. They have contributed to our sense of cultural identity and are important for recreation and spiritual enrichment. To Aboriginal people, the land has deep spiritual, economic, social, protective and recreational significance. Native plants and animals provide traditional medicines and raw materials for crafts, tools and ceremonial regalia. The conservation of biological diversity can therefore contribute to the maintenance of an Aboriginal cultural identity.

It can also be argued that all species and communities have an inherent right to exist. They form a part of a world which is an independent whole, belonging to the future as well as to the present, and which no species can claim its own. Ultimately, the actions of any species, including humans, will be guided by ecological limits.

What do we have to lose?

Australia's biological diversity is rich and unique, numbering about 475 000 species: 225 000 insects and invertebrates, 5 800 vertebrates, 44 000 plants and 200 000 fungi. The fauna of coastal waters surrounding the Australian continent is among the most species-rich and diverse on earth.

Much of this diversity is unique. More than 80% of our plant and animal species occur only in Australia (are endemic), far more than any other country. At the species level, 90% of our mammals, 70% of our birds, 85% of our flowering plants, 88% of our reptiles and 92% of our frogs are endemic.

The reason for this lies in Australia's evolutionary history. About 150 million years ago, when the ancestors of our modern plants and animals became established, Australia was thousands of kilometres to the south, connected by other southern continents to form the ancient super-continent Gondwana. More than 50 million years ago Australia, then mostly covered by rainforest, split from Antarctica and drifted north. Isolated from the rest of the world, its plants and animals evolved unique forms as they adapted to an increasingly dry environment.

Australia has species of evolutionary significance. The rain-forests in north-east Queensland provide some of the world's most important ancestral links in the history of plant evolution. Of 19 known families of primitive flowering plants, 12 are found in north-east Australia and two of these are found nowhere else in the world.

Australian habitats also offer their best chance for survival for a number of species which were once widespread. For example, the leathery turtle, the most endangered turtle species, has a

Research priorities

Researchers from many scientific disciplines are being brought together under CSIRO's new Biodiversity Multi-divisional Program. The program, coordinated by Dr Bryan Barlow from the Division of Plant Industry, aims to produce a national framework for conserving biological diversity and maximising its economic benefits.

The framework will be developed through the formulation of optimal land-use patterns and management guidelines. Pilot land-use models will be developed. Further research will focus on the effects of different influences on biodiversity and the role of biodiversity in economic development.

This research will provide a basis for developing integrated management systems. The key outcome is the optimal mix of regional land-use categories, with management guidelines, that together achieve the objectives of the National Strategy for the Conservation of Australia's Biological Diversity (see page 26). The program will study the location, design and management of reserves and the management of biological diversity in landscapes used for production.

Five CSIRO divisions (Entomology, Forestry, Plant Industry, Soils and Wildlife and Ecology) are taking part in the program's four areas of research. These are: characterising, estimating and sampling biodiversity; the sustainability of rural production systems; maintaining biodiversity and optimising resource management.

The program is the core element of CSIRO's broad involvement in biodiversity research. It will drive coordinated activities involving state and federal agencies and industry.

Global concern

Unprecedented concern about gene, species and ecosystem loss worldwide inspired the Convention on Biological Diversity, signed by Australia on World Environment Day (June 5, 1992) at the Earth Summit in Rio de Janeiro. The convention has now been ratified by more than 30 countries, including Australia, and came into force on December 29, 1993.

The convention encourages countries to conserve biological diversity, use its components in ways that are sustainable, and share equitably the benefits of using genetic resources. It offers a framework for maintaining the Earth's variety of life, and provides for the needs of developing countries, including access to financial resources and relevant technologies.

Nations party to the convention are required to develop national strategies for the conservation and sustainable use of biological diversity and to integrate these objectives into their national plans and policies for areas such as agriculture, fisheries, forestry and land-use planning.

Enhancing knowledge of biological diversity and the impacts on it are important measures addressed in the convention. Parties are required to identify and monitor ecosystems, species and their genetic components, as well as the processes and activities likely to affect them. These are important steps in determining conservation priorities.

Parties to the convention must undertake measures relating to:

- in-situ (in natural surroundings) and ex-situ (outside natural habitats, such as in zoos) conservation;
- sustainable use of biological diversity;
- incentives to encourage conservation and sustainable use;
- improved public understanding of biodiversity and the need for its conservation;
- access to and transfer of relevant technologies, and
- the provision of financial resources to enable developing countries to implement the convention provisions.

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few nesting sites in Australia but is heavily exploited elsewhere.

Two centuries of change

Human activity has been changing Australian ecosystems for about 60 000 years, but the pace and extent of change has risen since European settlement.

Upon arrival in Australia, settlers applied European land management regimes. This meant large-scale alteration of landscapes for agriculture and pastoralism. But unlike Europe, where such practices were sustainable, these changes were wrought quickly, under different soil and climatic conditions. Little incentive existed for sustainable land management practices because land was, by European standards, in endless supply.

Living systems can adapt to change. But in 200 years many Australian environments have changed at an unprecedented rate, in many cases too fast for the flora and fauna to adapt. Nearly 90% of temperate woodlands and mallee, and 50% of the rainforests have been cleared. More than 50% of agricultural land now needs restoration because of salinisation, waterlogging, soil erosion and other degradation.

One hundred plant species, 17 mammals and three birds have been lost. At least three frogs, including the unique gastric-brooding frogs of Queensland, seem to have disappeared. Many more species are threatened, endangered or extinct at a regional level.

Why have we lost biodiversity?

Ecosystem degradation limits the capacity of natural systems, and the species they comprise, to survive environmental change. Following are some of the major threats to Australia's ecosystems:

Clearing of native vegetation: Land degradation is perhaps the greatest threat to Australia's biological resources. It results from clearing or severe modification of perennial native vegetation and subsequent inappropriate land management. Forestry, mining, infrastructure and urban development also degrade the environment.

Productive capacity is reduced or eliminated through soil erosion and structural decline, salinity, waterlogging and inappropriate or excessive

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use of fertilisers and biocides, or contamination with other toxins. Degradation often affects adjacent uncleared areas, reducing their ability to support natural communities.

In the eastern temperate belt of Australia more than 90% of the native vegetation has been removed and replaced by introduced pastures and crops. Increasingly homogeneous landscapes lead to pest outbreaks and loss of resilience in biological communities. The greatest declines in native species have occurred in areas supporting the bulk of the sheep and wheat industries.

The lag effect of fragmentation extends over decades, and species often only finally disappear from an area many years after the events that set their extinction in train. Work by the Division of Wildlife and Ecology in the Western Australian wheatbelt (see page 30) has shown that bird species are still disappearing as a result of clearing several decades ago.

Water quality is closely related to land degradation. Changed water regimes, with greater run-off and soil erosion caused by clearing, lead to siltation, erosion of banks and greater turbidity. Increased nutrient input from agricultural run-off and discharge of domestic and industrial effluents lead to eutrophication (see 'Repairing Australia's rivers' *Ecos* 76). Toxic chemical and oil spills are also a threat to aquatic environments.

Richard Hobbs

Introduced plants and diseases: About 20 mammals, 30 birds, 21 fish, 500 invertebrates and 1500 plants have become naturalised in Australia.

Exotic species can have direct effects as competitors, predators, parasites or diseases of native wildlife. Habitat degradation caused by introduced rabbits and hoofed livestock, and predation by foxes and cats were the major reasons for the loss of Australia's 20 extinct mammals. New methods for min-imising the impact of vertebrate pest species are being developed at the Cooperative Research Centre (CRC) for Biological Control of Vertebrate Pest Populations. This CRC is located at CSIRO's Division of Wildlife and Ecology in Canberra.

Exotic plants can invade and in some cases completely replace native plant communities. Resource-use industries, such as mining and forestry, operating in remote and relatively undisturbed areas can facilitate their spread. The transfer of species from one part of Australia to another outside their natural range can also threaten biodiversity.

Mimosa pigra in tropical Australia, bitou bush in coastal Australia and bridal creeper in southern Australia are all weeds that degrade the environment. As they move into new habitats they out-compete plants that support animals, threatening these plants as well. Scientists at CSIRO's Division of Entomology are working to restore the balance by introducing the natural enemies of some of Australia's worst weeds.

Climate change: Determining the effects of climate change on natural ecosystems involves more than assessing the effects on individual species. Ecosystems function through complex relationships, such as those of predator and prey, pollinator and food source and parasite and host. Nutrient cycling plays a major role in the way ecosystems function. Any climate change which affects these processes would have significant consequences for natural ecosystems.

Future climate change is likely to be rapid. Given regional variations, the rate at which a particular ecosystem will have to respond to these changes may be unprecedented. In many instances, climate also determines processes of maturation and influences patterns of dispersal. Many ecologists have expressed concern that climate may change faster than species can adapt.

Recent Australian studies show that many of the species which are already threatened are sensitive to changes in climate. In some instances, climate change will place yet another survival pressure on species which are struggling to cope with competition from introduced species, habitat fragmentation and changes in land use.

Uncontrolled exploitation and trade in wildlife: The resources for controlling Australia's domestic and international trade in wildlife are inadequate, according to the director of Trade Analysis of Flora and Fauna in Commerce (TRAFFIC) Oceania, Debra Callister.

To prevent further losses of biodiversity, these processes must be controlled. Effective management of biological diversity is considered critical to our economic success. Australia's early record in this area is poor and the losses have proved detrimental to the country's long-term economic welfare. It is now realised that old operating methods based on short-term gain must be replaced by new techniques based on long-term sustainability and healthy ecological processes.

Ecosystems of humanity

United States ecologist Paul Ehrlich traces humanity's present dilemma to the agricultural revolution some 10 000 years ago. In a new book called *The Reconstruction of Fragmented Ecosystems – Global and Regional Perspectives* (see page 30) Ehlich writes that farming gave humans the means to exceed local long-term carrying capacities and to increase vastly the scale of the human enterprise. Humanity has since altered 'every ecosystem on the planet'.

Since the 19th century, humanity has become a global force, altering more than half the Earth's surface through building, road-making, farming and forest exploitation, and has changed the composition of the atmosphere, Ehrlich says. The results include regional and global water pollution, the acidification of entire landscapes and the rapid fragmentation and degradation of natural ecosystems.

Recent United Nations evaluations suggest that population growth may not halt until there are 14 billion or more human beings. This implies a near tripling of environmental impacts, Ehrlich warns. Environments are being altered at an accelerating rate with an accompanying loss of biodiversity, and restoration ecology has yet to make a significant dent in the job of ecosystem reconstruction.

Ehrlich argues that despite this gloomy outlook, every ecosystem that is restored is a step in the right direction, even if restoration is temporary. Techniques of restoration ecology must be perfected so that when expansion of the human enterprise ends, the tools will be at hand to refurbish natural systems.

Fortunately, there is growing recognition that population growth must be controlled. Ehrlich says many governments (notably the US) 'turn a blind eye' to the problem, but the population can be limited to 10 billion if a major effort is begun soon. He says it is also widely recognised that the mix of energy technologies must be altered to achieve a total energy use more than twice that of 1990, yet avoid a situation that would produce catastrophic environmental impacts.