The natural landscape

The Australian landscape comprises Australia's land, water and biodiversity (i.e. the native and introduced plants and animals that rely on them). They are inextricably linked. Changes in the condition of Australia's land, such as increased salinity, can affect inland waters and biodiversity. Changes in the health of our inland waters (such as reduced river flow) can affect biodiversity. The clearing of native vegetation can impact on biodiversity, and lead to land degradation and a decline in the health of inland waterways.

The commentary that follows comprises three subsections:

- Biodiversity: Our native plants, animals and ecosystems bring important economic benefits, are valuable to society and are globally important. Native bushland has cultural, aesthetic and recreational importance to many Australians. Most importantly, the ways in which organisms interact with each other and their environment are important to human survival: we rely on ecosystems that function properly for clean air and water and healthy soil. Headline indicators that consider changes in the condition of several groups of threatened species, and the annual area of land cleared, are presented. The commentary includes information about threats to Australia's biodiversity, as well as information about the action that is being taken to protect Australia's land and conserve biodiversity.

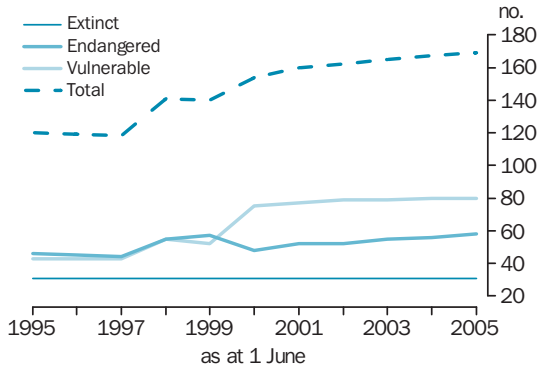
- Land: The condition of the soil covering Australia's land has a critical impact on our terrestrial ecosystems. Our soil resources are an important natural asset, and their health is a significant concern to Australian farmers, governments and the general public. Meanwhile the way in which Australia's land is used has a significant impact on our biodiversity and Inland waters. A headline indicator that considers the assets at risk of salinity is presented, and information on land use and forest cover is presented.

- Inland waters: Water is fundamental to the survival of people and other organisms. Apart from drinking water, much of our economy (agriculture in particular) relies on water. The condition of freshwater ecosystems has a critical impact on the wider environment. A headline indicator that considers the proportion of Australia's water management areas where water use is approaching or exceeding sustainable limits is presented. Information on Australian water use and water extractions from the Murray-Darling Basin is also included.

The commentary and statistics that follow use a range of information. Two sources that have been used considerably are *The State of the Environment Report* for 2001 (the latest available at the time of printing), and various publications from the National Land and Water Resources Audit.

The natural landscape: key points

Biodiversity: Extinct, endangered and vulnerable birds and mammals(a)

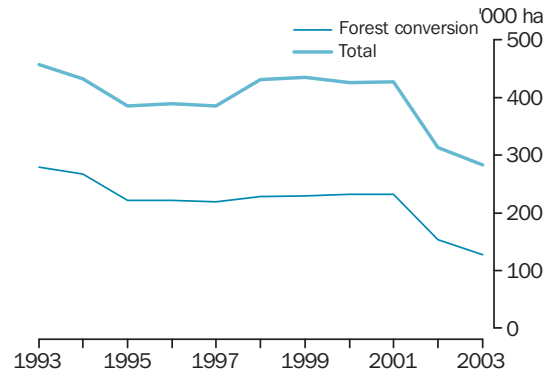


(a) Excludes seabirds, marine mammals and animals living on islands far offshore. Extinctions data have been backcast to take account of rediscoveries. Includes subspecies. There is likely to be a time lag between a species being identified as threatened and being listed.

Source: Data compiled from schedules to the Commonwealth Acts: the Endangered Species Protection Act 1993 and the *Environment Protection and Biodiversity Conservation Act 1999.*

Between 1995 and 2005 the number of terrestrial bird and mammal species listed as extinct, endangered or vulnerable rose by 41% from 120 to 169. Changes to the list of threatened species should be treated cautiously as species can be added to or removed from the list as their status changes or due to improved knowledge about their status.

Biodiversity: Annual area of land cleared (hectares)



Source: National Greenhouse Gas Inventory (NGGI), Australian Greenhouse Office 2005.[1] *The 2004 NGGI is scheduled for release in late May 2006.*

The rate of clearance decreased by about 38% between 1993 and 2003. Estimates indicate that about 283,000 hectares (ha) of land were cleared in 2003, with just over half (51%) in Queensland.

The relationship of biodiversity to progress

Our native plants, animals and ecosystems bring significant economic benefits, are valuable to society and are globally important. Most importantly, the ways in which organisms interact with each other and their environment are important to human survival: we rely on ecosystems that function properly for clean air and water and healthy soil.

About the headline indicators and their limitations: Extinct, endangered and vunerable birds and mammals, annual area of land cleared

No single indicator can hope to encapsulate biodiversity, and so we focus on two aspects: the numbers of extinct and threatened terrestrial Australian birds and mammals; and the annual area of land cleared.

Although the numbers of threatened birds and mammals are only a small part of the overall biological diversity, a decline in these groups of species threatens ecological processes and can point to a wider decline in biodiversity.

Land clearing is a key threat to biodiversity.[2] The land clearing estimates include information about forest conversion (land cleared for the first time) and reclearing, both of which have environmental impacts. The figures do not distinguish between the kinds of vegetation cleared.

Biodiversity: Other indicators

Trends in threatened species; Proportion of ecosystems: area protected.

Some differences within Australia

The 2001 National Land and Water Resources Audit report that threatened birds are declining across 240 of Australia's 384 subregions and threatened mammals are rapidly declining in 20 subregions and declining in 174 subregions.

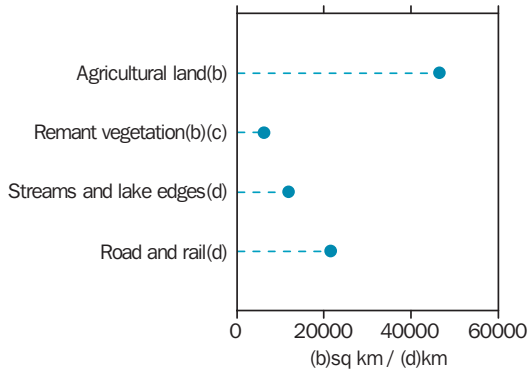
Land clearance since 1788 has mainly occurred in southern and eastern Australia. Just over half (51%) of land cleared in 2003 was in Queensland, but this is a reduction from 58% in 2002. Further decreases are expected as a result of ongoing policy initiatives by the Commonwealth and state Governments.

Links to other dimensions

See also the commentaries *The natural landscape – inland waters*, *The natural landscape – land, Oceans and estuaries*, and *National income*.

The natural landscape: key points

Salinity, assets at risk in areas of high potential(a) – 2000

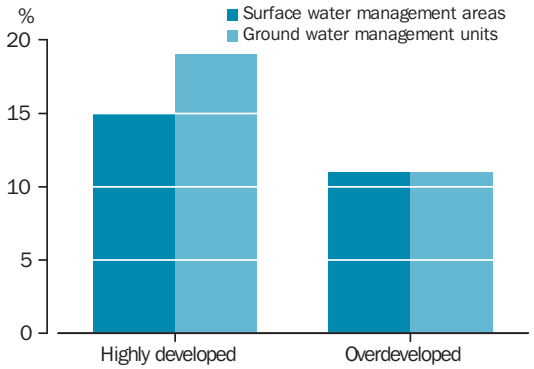


(a) The National Land and Water Resources Audit (NLWRA) defines land as having a high potential to be affected by salinity if groundwater levels are within two metres of the surface or within two to five metres with well demonstrated rising water tables. (c) Includes planted perennial vegetation.

Source: National Land and Water Resources Audit 2001, Australian Dryland Salinity Assessment 2000, NLWRA, Canberra.

In 2000, about 5.7 million hectares (ha) of Australia were assessed as having a high potential to develop dryland salinity through shallow or rising water tables.

Water management areas and units(a), proportion where use exceeded 70% of sustainable limits(b) – 2000



(a) Australia has 325 surface water management areas, based on the country's 246 river basins, and 538 groundwater management units (hydrologically connected water systems). (b) A highly developed water source is one where 70%–100% of the sustainable yield of water is extracted. An overdeveloped water source is one where more than 100% of the sustainable yield is extracted.

Source: National Land and Water Resources Audit 2001, Australian Water Resources Assessment 2000, NLWRA, Canberra.

The damming and regulation of waterways and extractions of both surface and ground water are leading to a continuing deterioration of the health of water bodies, while increasing salinity is causing deterioration in many areas. In 2000, about one-quarter of Australia's surface water management areas were close to, or had exceeded, sustainable extraction limits.

The relationship of land and inland water to progress

Our soil resources are an important natural asset. Degraded soil reduces agricultural productivity, while salinity can damage buildings and infrastructure such as water pipes, roads and sewers. Degradation can also damage habitat for wildlife, kill micro-organisms that live in the soil, and harm the quality of our inland waters.

Water is fundamental to the survival of people and other organisms. Apart from drinking water, much of our economy (agriculture in particular) relies on water. The condition of freshwater ecosystems has a critical impact on the wider environment.

About the headline indicators and their limitations: Assets at risk of salinity and water management areas exceeding sustainable limits

There are several forms of soil degradation in Australia. We focus here on dryland salinity, the impacts of which are wider than lost agricultural production and include damage to water resources, biodiversity, pipelines, houses and roads.

Ideally the headline indicator for inland waters would consider the health of Australia's freshwater ecosystems. But such data are unavailable for much of the country, so we focus on water use, and consider the proportion of Australia's water management areas within which water extraction is thought to exceed 70% of sustainable limits.

Land and water: Other indicators

Native forest area, Water diversions: Murray-Darling Basin; River condition biota index; Net water use; Total water storage capacity of large dams; River environment index.

Some differences within Australia

By 2050, more than half of Australia's dryland salinity problems are predicted to occur in Western Australia, with the south-west of that state particularly affected. New South Wales had more significantly, severely and extremely impaired river sites than any other state.

Links to other dimensions

See also the commentaries *The natural landscape – biodiversity, Oceans and estuaries*, and *National income*.

The natural landscape — biodiversity

Progress and the headline indicators

Our plants, animals and ecosystems bring economic benefits, and are valuable to society. Some believe that the other life forms we share the earth with also have intrinsic value, regardless of whether they are of benefit to humans. Our biological diversity is globally significant (Australia is recognised as one of 17 'mega-diverse' countries, with ecosystems of exceptional variety and uniqueness).[3] Most significantly, the ways in which organisms interact with each other and their environment are vital to human survival: we rely on ecosystems that function properly for clean air and water and healthy soil.

Ideally, the headline indicator would consider all Australian biodiversity – the abundance and diversity of micro-organisms, plants and animals, the genes they contain and the ecosystems which they form. To measure change as comprehensively as this would be difficult, if not impossible, and so here we focus on two indicators. The first is changes in the conservation status of one small component of biodiversity – terrestrial mammals and birds (although it must be remembered that the conclusions drawn from these two groups cannot necessarily be applied to other animals and plants). The second indicator is the annual area of land cleared – a key threat to our biodiversity.

Mammals and birds

The numbers of threatened species are one aspect of biodiversity that can be measured. Mammals and birds are used as indicator species, as scientists have more information about these groups than many others, and they are often visible in the landscape and the most easily identified. Although the numbers of threatened birds and mammals are only a small part of overall biological diversity, a decline in these groups of species may point to a wider decline in biodiversity. Some species at the top of the food chain can highlight problems such as the accumulation of contaminants (e.g. pesticides), which can cause eggshell thinning in species like the white-bellied sea-eagle and the threatened red goshawk. [4,5]

Changes to the list of threatened species should be treated cautiously. Species can be removed or added because of improved knowledge or sometimes new species are discovered, or those thought extinct are rediscovered. That said, over time, if the numbers of threatened birds and mammals increase substantially there is reason to believe that certain species are declining.

Between 1995 and 2005, the number of terrestrial bird and mammal species assessed as extinct, endangered or vulnerable rose by 41% from 120 to 169 (of which 67 were birds and 102 were mammals). In June 2005, just under half of these species were vulnerable, one-third were more seriously threatened (endangered) and the remaining fifth were presumed extinct. There were increases in the numbers of both endangered and

A longer term view

Declines in wildlife have occurred in most parts of Australia since European colonisation. Intensive land use, which has played a part in the decline, has been concentrated in the south and east of the country. Habitat loss, through cropping, grazing, forestry, mining and human settlements, has dramatically changed vegetation cover. Since 1788, around 20% of woodland and forest (over 700,000 km^2) have been cleared or thinned, primarily for crops and grazing. Around 35% of mallee (130,000 km^2) have been cleared since 1788, along with 45% of heath (20,000 km^2), 10% of tussock grassland (over 60,000 km^2) and smaller areas of other grasslands.[6]

Since European settlement, land clearance has been concentrated in certain areas and ecosystems. Generally those ecosystems found on the most fertile soil have suffered the highest levels of clearance, and about 90% of native vegetation in the eastern temperate zone has been removed.[7] In other areas, pressures such as grazing (both from domestic stock and introduced herbivores), weeds and changed patterns of fire are having an impact on the land. More than 90% of land clearance has occurred in 25 of Australia's 85 bioregions (areas of land that contain linked ecosystems). These bioregions occur across south-west Western Australia, southern South Australia, most of Victoria and New South Wales, and central and southern Queensland.[6]

Wildlife has declined even in areas of Australia where the level of land clearing has been lower. In the arid zone, about one-third of mammal species are regionally extinct, the highest extinction rate on the Australian mainland, and many birds are declining.[8] The extent of cattle grazing, effects of invasive species and changes to fire regimes are factors thought to have led to a decline in many animal species in these areas.

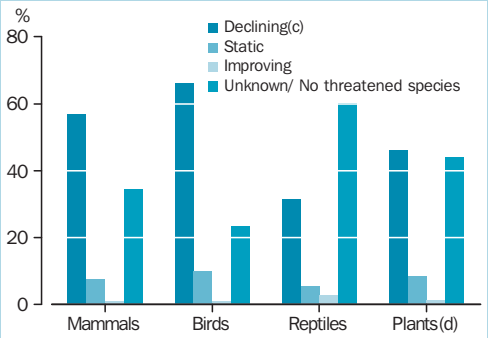
Over the past 200 years, 17 mammal species (out of around 270), and a further 7 sub-species, are thought to have become extinct in continental Australia. Fewer than 25 species are believed to have become extinct in the rest of the world over the same period, which means that Australia accounts for over 40% of the world's mammalian extinctions since 1800.[9] Some other mammals, once widespread, now survive only in tiny areas (often islands free of foxes and cats); this isolation and loss of genetic diversity make species less adaptable and more vulnerable to threats such as disease.

More than 20 exotic mammals and 20 exotic birds have become established in Australia since 1788. But it is hard to compare these with the species we have lost. All of the Australian mammals to have become extinct, for example, were found nowhere else in the world. Most of Australia's exotic bird and mammal species, however, are common elsewhere in the world. Most have brought environmental problems with them since their establishment here.

Conservation status

Since 1993, the Commonwealth Government has maintained a list of threatened and extinct species and subspecies. A species is designated as *vulnerable* when there is strong evidence that it faces a high risk of extinction in the medium term, and *endangered* if it faces a very high risk of extinction in the near future. A species is classed as *critically endangered* if it faces an extremely high risk of extinction in the immediate future and *extinct* if there is no reasonable doubt that the last member of the species has died.[10]

Trends in threatened species(a), proportion of bioregions(b)



(a) Median trend in threatened species condition. (b) Australia has 384 subregions. (c) Includes the categories 'extinction' and 'rapidly declining'. (d) Vascular plants.

Source: National Land and Water Resources Audit, 2002.

Changes in the condition or status of threatened flowering plants, birds, mammals and reptiles are only a part of overall biological diversity, but a decline in these groups of species threatens ecological processes and can point to a wider decline in biodiversity.

In 2002, the National Land and Water Resources Audit (NLWRA) released an assessment of Australian biodiversity, that was based on a mixture of qualitative and quantitative data from around the country.[11] They reported the median changes in the condition of groups of threatened species in each Australian bioregion.

- Threatened flowering plants were declining across 177 of Australia's 384 subregions; static in 33 and improving in five.
- Threatened birds were declining across 240 subregions; had gone extinct in a further 14; were static in 38 subregions; and improving in three.
- Threatened mammals were declining in 194 subregions; had gone extinct in 24 subregions; were static in 29 subregions; and improving in four.
- Threatened reptiles were declining in 119 subregions; had gone extinct in 2 subregions; were static in 21 subregions; and improving in 11.

vulnerable species, but the rise in species assessed as vulnerable was much higher (86%) than those assessed as endangered (26%).

Australia's biodiversity: a world view

Australia's biodiversity is very rich. In 1998 Conservation International recognised 17 countries as *mega-diverse* because of their extraordinarily rich biodiversity, and together they account for some two-thirds of the world's species. Australia and the USA are the only two developed countries classed as mega-diverse.[12]

Australia is a large country and contains a great variety of habitats and ecosystems, from coral reefs and tropical rainforests to temperate woodland, deserts, semi-arid rangelands and alpine grasslands. It is, therefore, likely to have more species than many countries by virtue of size alone. But our fauna is highly endemic (that is, many Australian species are found nowhere else on Earth). About 90% of our reptiles and frog species are endemic, as are about 80% of our mammals and 85% of flowering plants.[8,13] We have 200 species of freshwater fish, 90% of which are endemic. Hooved animals, cats, canids (foxes and dingoes) and plants like thistles, for example, have been introduced and affected native biodiversity.

Far less is known about the world of invertebrates and micro-organisms, though Australia has several hundred thousand species of invertebrates.[14] There remains much to be learnt about our biodiversity. In 2000, for example, scientists announced the discovery of a new type of antibiotic – as powerful as penicillin – in the eggs of an Australian shellfish.[15]

Extinctions

Over the past 200 years many elements of Australia's biodiversity have declined, and species of mammals, birds, frogs and plants are presumed to have become extinct. Our mammals have been affected particularly severely: 17 of the 270 or so species of mammal that lived in continental Australia in 1788 are now presumed extinct, under the *Environment Protection and Biodiversity*

Presumed mammalian extinctions(a) since 1788 – 2005

Species	*Last record*
Darling Downs Hopping Mouse	1840s
Big-eared Hopping Mouse	1843
White-footed Rabbit Rat	1845
Gould's Mouse	1857
Broad-faced Potoroo	1875
Eastern Hare-wallaby	1889
Short-tailed Hopping Mouse	1896
Long-tailed Hopping Mouse	1901
Pig-footed Bandicoot	1901
Lesser Stick-nest Rat	1933
Desert Rat-kangaroo	1935
Tasmanian Tiger	1936
Toolache Wallaby	1939
Lesser Bilby	1950s
Crescent Nailtail Wallaby	1956
Central Hare-wallaby	1960s
Desert Bandicoot	1960s

(a) Excludes subspecies and extinctions from Christmas and Lord Howe Islands.

Source: A Gap in Nature[9], Mammals of Australia[16] and schedules to the Environment Protection and Biodiversity Conservation Act 1999.

Seventeen species of mammals (and another 11 subspecies) are listed by the Commonwealth as presumed extinct in mainland Australia since 1788. Ten of these species were last seen alive in the twentieth century, ten of these animals are marsupials, and 14 of them were found predominantly in the inland arid zone. However, other groups of animals have fared rather better, at least in terms of losses through extinction.

Numbers of species in selected countries(a)

	Mammals			Birds			Reptiles		
	no.	Endemic species	Endemic %	no. breeding species(b)	Endemic species	Endemic %	no.	Endemic species	Endemic %
Australia	260	206	79	649	350	54	748	641	86
Brazil	417	119	29	1 500	185	12	491	201	41
Canada	193	7	4	426	5	1	41	0	0
India	316	44	14	926	58	6	390	188	48
Indonesia	457	222	49	1 530	408	27	514	305	59
New Zealand	10	4	40	150	74	49	52	48	92
South Africa	255	35	14	596	8	1	315	97	31
Tanzania	316	15	5	827	24	3	289	61	21
United Kingdom	50	0	0	230	1	0	8	0	0
United States of America	432	105	24	650	67	10	287	79	28

(a) Data are approximate only and have been drawn from the World Resources Institute for the purpose of making international comparisons. (b) Breeding species are used because some species are migratory.

Source: World Resources Institute 2001, World Resources 2000-2001.[15]

Conservation Act 1999. Ten of these species were lost in the past 100 years.

The table on the previous page lists the mammal species (but not subspecies) that are believed to have become extinct in Australia since 1788. A further seven subspecies are presumed extinct, and several other species now survive on offshore islands or Tasmania but are extinct on the mainland. This compares with three extinct birds from about 700 species (another four subspecies have also become extinct), four extinct frogs from over 200 species, and 61 species of flowering plants from over 15,000 species. No freshwater fish or reptile species are known to have become extinct, though other species may have become extinct before they were ever recorded.

Land clearing

The clearing of native vegetation is a key threat to Australia's terrestrial biodiversity,[2] and perhaps the most significant threat to species and ecosystems in eastern Australia.[11] Land clearing destroys plants and local ecosystems and removes the food and habitat on which other native species rely. Clearing helps weeds and invasive animals to spread, affects greenhouse gas emissions and can lead to soil degradation, such as erosion and salinity, which in turn can harm water quality. Native bushland has cultural, aesthetic and recreational importance to many Australians.

Land is cleared for many reasons (particularly agriculture and urban development). Native vegetation is sometimes completely cleared (if crops are sown, for example). At other times only a proportion of the native vegetation is removed from an area, which may occur when land is used for mining or urban development.

Ideally, the headline indicator would consider the area of native vegetation cover in Australia. Such an indicator would require a weighted measure of the extent and intensities of land clearance and modification: few accurate time series data are available and so we use estimates of land clearance from the National Greenhouse Gas Inventory (NGGI). The estimates include the majority of intensive clearance of native vegetation. The estimates are based on continental satellite coverage. This allows distinctions to be made about whether the land has been cleared for the first time or not, however it does not distinguish between the kinds of vegetation that have been cleared – for example whether it formed part of a healthy or degraded ecosystem.

The estimated 283,000 ha of Australian land cleared in 2003 is 38% smaller than the 457,000 ha cleared in 1993. Of the land cleared in 2003, less than half (128,000 ha) was 'converted' (cleared for the first time), which is less than half the area (279,000 ha) converted in 1993.

Fire and biodiversity

There is a growing awareness of the links between fire regimes (the season, frequency, intensity and type of fires) and conservation of biodiversity. However, our knowledge of the responses of animals to fire is variable. Most research has focused on mammal and bird responses to fire, and mostly in forest, heathland and woodland ecosystems.

Experts believe that fires have tended to be less frequent since European settlement with more fuel to power them, and they have been more intense and, in some areas, more destructive as a result. In other parts of Australia, it is thought that a greater number of low intensity fires can be more damaging to biodiversity than fewer high intensity fires.

Data from NSW[17] indicates that the number of bushfires is seasonal, increasing steeply between September and January. In 2002–03, the number of fires per month during this period ranged from 76 to 113. Fires that occur at this time (spring and early summer) can disrupt species' breeding seasons. Some animal species increase their abundance after fire, such as birds in the woodlands of northern Australia. And some species are dependent on fire or fire regimes for their survival, particularly in northern Australia.[18]

Threatened species and their conservation

Swift Parrot

The swift parrot (*Lathamus discolor*) is a threatened parrot that migrates between Tasmania, where it breeds, and the Australian mainland. There are estimated to be less than 2,500 individuals left, and the success of their breeding season is linked to the supply of nectar from flowering blue gums, their main source of food. Threats to the survival of the swift parrot include the widespread clearing and fragmentation of the woodlands and forests for agriculture, urban and coastal development. Forestry and firewood collection has depleted breeding (nest hollows) and feeding (nectar) resources by removing older trees, and swift parrots are also vulnerable to collisions with man-made structures such as vehicles. The National Swift Parrot Recovery Program was established in 2001, with one of the main aims to improve the quality of swift parrot habitat. An annual survey is undertaken as part of this Program to monitor swift parrots.[19]

Southern Corroboree Frog

The yellow and black southern corroboree frog (*Pseudophryne corroboree*) is restricted to the sub-alpine areas of Kosciuszko National Park, NSW. The frogs have experienced a gradual decline and their geographic range has contracted. Vegetation types such as sphagnum bogs, wet tussock grasslands and wet heath that have pools and seepages serve as breeding habitat. Threats to the frog include climate change, increased UV radiation, disease, former livestock grazing of the alpine region, construction activities associated with the Snowy Mountains Hydro-Electric Scheme and ski resorts, collecting by people, potential weed invasion, and feral animals. The Recovery Plan for the frog, implemented in 1999, had the main objective to downlist the species from critically endangered to endangered within ten years, and this has been achieved with the frog currently listed as endangered.[20,21]

Mahogany glider

The Mahogany glider *(Petaurus gracilis)* is a relatively large gliding marsupial which lives in medium to low woodland in a severely restricted distribution in north-eastern Queensland (an area of approximately 720sq km between Crystal Creek and the Hull River in the Wet Tropics). The total population of this species has been estimated at 2,500. The main threats to this species are the loss and fragmentation of habitat through land clearing. Other threats include wild fires, disease, cyclones and transport corridors as well as habitat changes such as rainforest expansion and weed invasion. Much of the gliders habitat occurs outside of protected areas. Long-term survival of the species therefore requires a broad-based approach to habitat protection outside national parks and declared critical habitat areas. Engaging the community in the recovery of the mahogany glider through landcare programs, economic incentives, community education and further research are important to the survival of the species. Encouraging landholders to retain as much habitat as possible, and the linking of habitat fragments will assist in the creation of sustainable populations.[22,23]

Macquarie Perch

The threatened Macquarie perch (*Macquaria australasica*) inhabits the Murray-Darling River system in Victoria, New South Wales and the ACT, along with coastal populations in the Nepean, Hawkesbury and Shoalhaven Rivers. Fish populations that have previously been translocated to other riverine sites rarely survived, and they are difficult to breed in captivity. For this reason, conservation stocking programmes are not viable for this species. Threats posed to the Macquarie perch include reductions in water quality from agriculture, forestry and urbanisation (particularly sedimentation), the modification of natural river flows and temperatures as a result of river regulation, spawning failures from cold water releases from dams, competition from introduced fish, diseases, and overfishing. There is currently a draft national recovery plan in preparation for the Macquarie perch. In addition, some of the major conservation objectives outlined by the ACT are to maintain viable populations of Macquarie perch, to maintain the species' potential for evolutionary development in the wild, and to protect habitat and sites crucial to survival. [24,25,26]

Some differences within Australia

The numbers of extinctions in different states and territories depend on many factors such as the types of ecosystems within a state, the level of human disturbance and the impact of exotic species. But among the states and territories, South Australia has lost more mammals than any other state: at least 28 species of mammal are presumed extinct from that state (though here, as in other states, some of these animals continue to survive elsewhere in Australia). New South Wales has also lost many species (26), and Victoria (21). The Northern Territory has lost an estimated 14 mammal species, Western Australia has lost 11 and Queensland 6. The Australian Capital Territory does not maintain a list of extinct mammals, although in recent times only 1 species is believed to have been lost (the Brush-tailed Rock Wallaby), while Tasmania is thought to have lost the Thylacine but no other mammal species since 1788.[27]

As well as considering individual species, it is useful to consider entire ecosystems, which are the result of long-term interactions between the physical environment and living species. The area of land in conservation reserves is one possible indicator of the extent to which ecosystems are protected. This has been increasing and just over 10% of Australia's land was protected in areas such as national parks in 2002.[28] Among the states and the territories, in 2002 the ACT had the largest proportion of land in conservation reserves (54%), followed by Tasmania (37%), South Australia (26%) and Victoria (15%). Only 4% of Queensland was in reserves along with 5% in the NT, 7% in New South Wales and 11% in Western Australia.[28]

There are many examples of specific change, for the better or worse, in every state. For example, fox control in Western Australia helped the numbers of several threatened marsupials to increase over the 1990s, while in 2001 the NSW Government declared six woodland bird species to be vulnerable, primarily because of habitat clearing and fragmentation.[29] Many endangered species face

Invasive Species – animals

Many of Australia's most serious animal pests (invasive animals) were introduced deliberately, and species are still being introduced, deliberately and accidentally. Foxes, though present on the mainland were first sighted in Tasmania in 2001, the establishment of fire ants in Brisbane (now apparently under control), and the discovery of several species of exotic ants in the Northern Territory are new concerns. It was estimated that in 2002, 30 of the more serious animal pest species cost the economy at least $420m a year (mainly in lost agricultural production).[30]

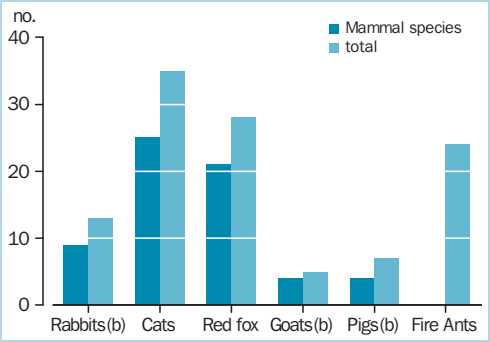
Invasive Species – plants

A plant which has, or has potential to have, a detrimental effect on economic, conservation or social values, is considered to be a weed.[31] In 2001–02 weeds (invasive plants) were estimated to have cost the Australian economy $4 billion, $3.9 billion in lost agricultural production and cost of weed control, and $100 million in weed control on national parks and Indigenous land.[32] The economic impact of weeds on natural environments, beyond the cost of weed control are unknown.[32]

Birds and mammals threatened by invasive species

The *Environment Protection and Biodiversity Conservation Act 1999* lists processes which threaten native species. This list of key threatening processes includes a number of invasive animals. The graph shows the number of bird and mammal species listed as threatened by these invasive animals (some native species are threatened by more than one invasive animal). In 2006, feral cats were listed as threatening 25 mammals and 10 bird species with extinction, while foxes threatened 21 mammals and seven bird species.

Species-threatening invasive animals, number of species threatened(a)



(a) Key threatening processes listed under the *Environment Protection and Biodiversity Conservation Act 1999*. Includes subspecies. Species threatened on Christmas and Norfolk Islands are excluded. (b) The threat includes associated threats such as land degradation.

Source: Threat abatement plans, Department of Environment and Heritage, Australia, March 2006.[33]

International comparison – annual rate of change of forest area

There is no OECD indicator available that is directly comparable to the MAP headline indicator for biodiversity: annual area of land cleared. An indicator available for OECD countries for a related concept is the change in forest area.

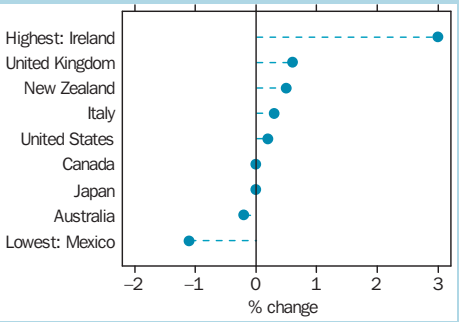
The change in forest area provides an indication of the balance between forest growth and forest harvesting or clearing. Forests are an important component of biodiversity, as they provide habitat for many plant and animal species, perform ecosystem functions such as water filtration, and act as carbon sinks. The change in forest area provides some indication of the sustainability of forest management and land clearing in a particular country.

Change in forest area is expressed as the annual rate of change, and considers the net change in forest area in terms of the balance between the growth and use of natural forests, and includes the expansion of forest plantations. A negative change in forest area indicates that the harvesting or clearance of forest exceeds growth.

Between 1990 and 2000 the annual change in forest area in Australia was -0.2%. Australia was one of four OECD countries where the harvesting and clearance of forest exceeded growth. The largest annual loss of forest area occurred in Mexico (-1.1%). The majority of OECD countries experienced increases in forest area during the period between 1990 and 2000. Ireland experienced the largest annual increase of 3%.

See also the international comparison for Protected areas in the *Some international comparisons of progress* essay on page 189.

Forest area annual rate of change – 1990 to 2000



Source: State of the World's Forests 2005, Food & Agriculture Organisation of the United Nations.[34]

more than one threat. The box on the previous page looks in more detail at four of Australia's endangered animals, and discusses why they are assessed as threatened and what is being done to protect them.

Just over half (51%) of land clearance in 2003 occurred in Queensland where an estimated 145,000 ha were cleared. New South Wales cleared 75,000 ha and Victoria cleared 22,000 ha. Clearance in the other states and territories ranged from about 3,000 to 18,000 ha. Estimated rates of clearance before 1990 are less accurate, although the NGGI figures indicate that land clearance in Queensland was continually higher than in any other state between 1970 and 1990. Over a longer period, however, other states have cleared a greater proportion of their land than Queensland, which has cleared 18% of land compared to around 30% in New South Wales and the Australian Capital Territory and 60% in Victoria.[6]

Protecting Australia's land

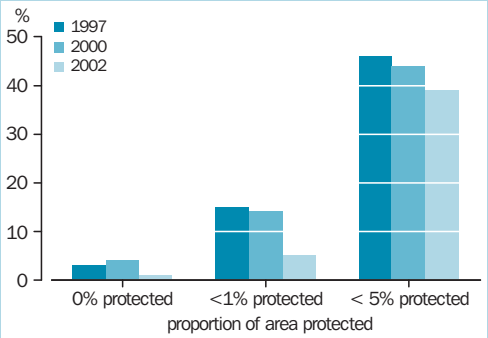
While the pressures to clear land remain, Australians are responding to protect bushland. Ideally one would consider the total area of land that is being managed by government, organisations and individuals to conserve biodiversity. But current information on the area of all such land is not available. However, there are recent data on the area of land protected inside conservation reserves. This is growing, and, in 2002, over 77 million ha (just over 10% of Australia) were in protected areas. This is an increase of about 18 million ha since 1997. Some ecosystems are protected better than others: the chart right shows that, in 2002, 33 of Australia's 85 major biogeographic regions (IBRAs) had less than 5% of their area protected (down from 37 IBRAs in 1997); four of these regions had less than 1% of their area protected (down from 12 IBRAs in 1997) and one region had no area at all within the reserve system (down from two IBRAs in 1997).[28] Legislation, such as the native vegetation acts enacted in Queensland, New South Wales and South Australia in the 1990s, targeted at controlling the clearing of native vegetation are now in force.

Australia has international obligations concerning its protected land, such as World Heritage listed sites and Ramsar wetlands. World Heritage sites are nominated areas that have outstanding natural and/or cultural values. Australia has 15 World Heritage sites listed for natural values[35], with Kakadu National Park, Uluru-Kata Tjuta National Park, Willandra Lakes Region and the Tasmanian Wilderness also listed for cultural values.

Ramsar wetlands are wetlands of international importance. They are valued for their ecology, their plants and animals, or for the ponds or lakes themselves and the hydrological functions (such as water filtration) they perform. Australia has 64 Ramsar wetlands[36] and is signatory to international conventions to protect migratory species that use these wetlands, such as the Japan-Australia Migratory Bird Agreement and the China-Australia Migratory Bird Agreement.[37]

With 63% of Australian land in private ownership,[38] efforts to protect biodiversity now extend beyond the reserve system into some of this private land. This occurs through community landcare groups and conservation agreements made between landholders and the government. Some companies and community groups also operate conservation reserves. Indigenous communities are involved in managing land, with Kakadu, Uluru-Kata Tjuta and Booderee National Parks all managed jointly with traditional owners and the Australian government through the Director, National Parks. This provides an emphasis on maintaining and strengthening traditional ties with the land, which relies heavily upon ensuring the land and the ecosystems it supports are in good shape.[39]

Proportion of ecosystems(a), area protected



(a) Interim Biogeographic Regionalisation for Australian areas.
Source: Commonwealth Protected Areas Databases. [28]

Factors influencing change

Many factors threaten biodiversity. Species are often affected by more than one threat, and one threat can affect many species.

Change and disturbance are a natural part of every environment. But human activity almost invariably affects the direction and pace of change and the extent of disturbance, challenging the ability of ecosystems and species to respond.[40] Over the past 200 years, change in Australia has, by world standards, been great and rapid, and has had a profound effect on our biodiversity. The change has taken many forms, including large scale land clearance and the introduction of many exotic species, while the use of water, primarily for agriculture, has damaged the health of freshwater ecosystems.

A change to one part of the system can have important, sometimes unforeseen consequences elsewhere. The removal of native vegetation is an example: clearing plants removes the food that herbivores rely on, and consequently impacts on the carnivores higher up the food chain. Removal of plants can lead to soil erosion or the loss of soil nutrients: both processes reduce the biodiversity present among the vast array of minute species that live in the soil. And as a patchwork of vegetation is cleared, the remaining islands of native vegetation can be more vulnerable to damage from threats such as weed invasions, while the animals left within these islands may be isolated and so more vulnerable to events such as the bushfires in south-east Australia in recent years.

In 2002, the NLWRA concluded that vegetation clearing is the most significant threat to species and ecosystems in eastern Australia. Overgrazing, exotic weeds, feral animals and changed fire regimes are additional key threats across the country. And fragmentation of remnant native vegetation, increased salinity and firewood collection are threats to biodiversity in the highly modified regions of southern and eastern Australia.[11]

Another factor infuencing biodiversity is invasive species. Invasive species occur in all habitats and many invasive plants and animals are increasing in number and spreading across Australia. In 2002, 25 mammals, 20 birds, 4 reptiles, 1 amphibian and at least 23 freshwater fish species introduced from overseas were established in Australia,[11, 30] along with about 2000 plants.[41]

Introduced predators like the fox and cat have spread over much of Australia and have contributed to the decline or extinction of some native species, through predation or the spread of disease. Cane toads have advanced through Queensland to Cape York, south to Port Macquarie

Conserving biodiversity

Although Australia's biodiversity continues to be threatened by many factors, much is being done to protect our flora and fauna. Governments, non-governmental organisations, the private sector and local communities all play a part. Conservation is promoted in many ways including legislation, the mitigation of threatening processes (such as fox and weed control), land rehabilitation, scientific research and education. And the comprehensiveness of the nation's system of conservation reserves improved in the 1990s.[2]

The state and territory parks and wildlife services are working to conserve native flora and fauna, and in some areas endangered species are being reintroduced to areas where they were formerly present. Bridled Nailtail Wallabies and Yellow-footed Rock Wallabies have been reintroduced, for instance, to Idalia National Park in central Queensland. Operation Western Shield in Western Australia has significantly reduced fox numbers in parts of the State, and marsupials like the Numbat, Woylie (or Brush-tailed Bettong) and Chudditch (or Western Quoll) have increased in numbers. Other states and the territories are working on similar schemes, while nationally, urban conservation initiatives are involving more Australians in projects focused close to where they live and work. The recent *Bush Forever* initiative by the Western Australian Government is a good example: it identified regionally significant urban bushland to be retained and protected.[2] The area of land in protected reserves has increased over the past decade. Species recovery plans and threat abatement plans are also addressing many issues, though it is too early in some cases to gauge their effectiveness.

About 63% of Australia is held in private hands, either freehold or leasehold, and is managed for commercial use, and so private landowners can play a significant part in helping to conserve biodiversity.[38] Indigenous Australians' role in land management is increasingly recognised as important. Indigenous Australians manage around 15% of the country and they have an extensive understanding of Australian ecology from which others are learning.

Some industries are also beginning to show greater concern for protecting biodiversity. The mining industry, for example, has developed codes of practice for environmental management, and is employing biologists to help assess and minimise the impacts of mining operations.

The National Heritage Trust was set up by the Australian Government in 1997 to help restore and conserve our natural resources. It is the largest environmental rescue plan undertaken in Australia, and is expected to have spent $2.7 billion by 2007. Thousands of community groups have received funding for environmental projects.[40] Meanwhile other work, such as the National Action Plan for Salinity and Water Quality is underway to address Australia's natural resources, and some of these initiatives are discussed elsewhere in the Natural landscape commentary.[42]

Woodland restoration and birds

Ongoing commitment from government, community and industry is seen as the key to long-term success in the restoration of woodland habitats. Australians are volunteering their time, land and expertise to help reinstate woodland habitats.

The restoration of habitat for particular bird species is the focus of many current projects. Species such as the threatened Regent honeyeater and the Grey-crowned babbler are the focus of planting projects in New South Wales and Victoria respectively.

The success of some past revegetation projects has been assessed by Greening Australia ACT and South East NSW. In the 1990s Greening Australia invested substantial resources in revegetation projects in the local area. Extensive surveys conducted in these areas during the Birdwatch project in 2001 found that 109 bird species are now using revegetated areas, including threatened woodland species such as the Hooded robin, Speckled warbler and the Diamond firetail.

While many projects focus on revegetating land, it is recognised that retaining existing habitat is more effective for the conservation of woodland birds. Our knowledge of enhancing habitat on agricultural land has increased in recent years. We now know that:

- Even small (0.5ha) patches of remnant 'old growth' woodland provides habitat for a significant number of bird species.
- Logs provide habitat for ground dwelling and ground foraging species.
- Understory shrubs provide habitat for a variety of woodland species.
- Even where only a few trees remain, there will be a greater diversity of bird species than where all trees have been cleared.[43]

and into the Northern Territory. As well as preying on insects, small mammals and snakes, they are also poisonous, killing many animals that prey on them, such as goannas, quolls and birds.[30] Rabbits have at times reached plague proportions over much of Australia, competing with native animals for resources, overgrazing vegetation and damaging soil structure (through the digging of holes).

The National Weeds Strategy (last updated in 1999) identifies 20 weeds of national significance and another 28 species which pose a potential threat to biodiversity. About 350 weed species in Australia have been declared noxious.[44]

The National Weeds Strategy states that weeds are among the most serious threats to Australia's primary production and natural environment, and are increasingly moving into or towards almost all ecosystems of immediate economic, social or conservation value.[31] They displace native species, and the effects flow on to animals, such as insects and birds, that rely on native plants for food and shelter. Many weeds also interfere with agricultural production.

Weeds also cause environmental damage that is difficult to quantify. Some species cover very large areas. Blackberry ranges over 9% of Australia. Weeds also affect important conservation regions. Mimosa, which threatens the Kakadu World Heritage Area, can grow to a height of six metres, and produces so many seeds that it can double in area every year, turning species-rich tropical wetlands of northern Australia into a Mimosa

monoculture.[45] These weeds, and many more, pose a serious threat to biodiversity.

So-called sleeper weeds (weeds that are established or newly arrived but are not as yet a widespread problem) are now recognised to be of major concern.[2] For years Athel Pine did not pose a problem until the wet year of 1974, when thousands of seedlings, washed from homestead gardens, sprouted along inland waterways.[6] It now grows along water courses in central Australia, changing the river flow, displacing red gums and raising water tables thereby contributing to salinity.[8]

Weeds such as Gamba grass and Buffel grass interact with fire regimes and can displace native vegetation in northern Australia. These grasses produce fuel loads much larger than native grasses, and in the case of Gamba grass have a different life cycle. This results in fires of greater intensity and different timing that native trees, shrubs and grasses are unable to withstand.[46]

Weeds also cause flow-on effects. Some weeds are either more flammable or more fire retardant than the species they displace, and can alter the fire patterns of the communities they invade (which may have effects on native animals living in those communities). Other weeds provide food and shelter for invasive animals.

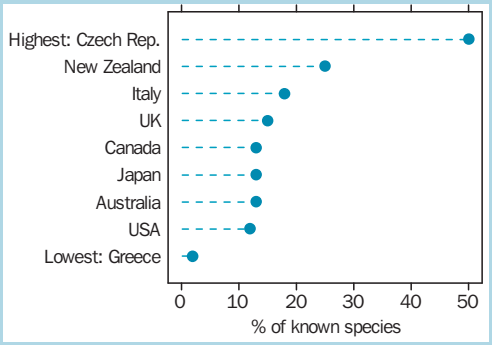
Outside their natural range or in increased numbers, native species may be as serious a threat to biodiversity as exotic ones. Many are spreading or increasing in abundance because of recent human activity. For example, large areas of grass and crops, together with more watering points have encouraged galahs to expand their range and colonise much of Australia, competing with other native birds for nesting sites.[8]

The problems caused by invasive species are widely recognised and work is being done to combat them. Effort for invasive plants is being focussed through the National Weeds Strategy. Threat abatement plans have been developed for the fox, rabbit, cat, pig and goat to combat their threat to endangered native species. A threat abatement plan for dieback fungus was adopted in 2001 to address this major threat to biodiversity.[47] And the Australian Quarantine and Inspection Service continues to develop new ways to prevent potentially invasive species from entering Australia.

Although in 2000 it was found that the growth of cities and towns has only affected land cover over a small area (less than 0.1%),[48] it can have regional effects. Most of the urbanisation has occurred around the coast, sometimes in regions of high biodiversity, while future housing development in some areas may entail clearing threatened (now remnant) woodland communities such as the Cumberland Woodland around Sydney.[49]

However, agriculture has been responsible for the majority of land clearance in Australia. Although about 60% (460 million hectares) of Australia is used for agriculture, clearing has been selective,

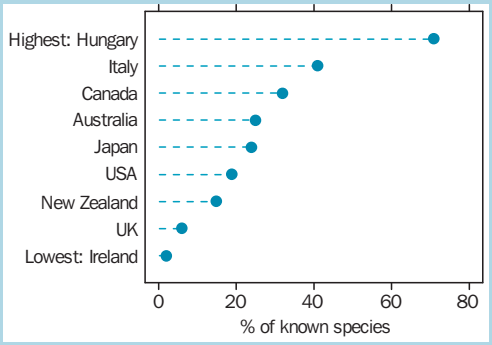
International comparison: threatened bird species – 2005(a)



(a) The information refers to the latest year for which data are available, which differs between countries.

Source: Environment at a Glance, OECD Environmental Indicators 2005.[50]

International comparison – threatened mammal species 2005 (a)



(a) The information refers to the latest year for which the data are available, which differs between countries

Source: Environment at a Glance, OECD Environmental Indicators 2005.[50]

Threatened species are one key indicator of the health of biodiversity. The threatened bird and mammal species indicators are expressed as the number of threatened species compared to the number of known or assessed species. "Threatened" refers to species which are classified as critically endangered, endangered or vulnerable.

In 2005, the proportion of bird species that were threatened is highest in the Czech Republic where 50% of the 220 known bird species in the Czech Republic are considered threatened. Hungary has the highest proportion of threatened mammal species with 71% of Hungary's 83 mammal species classified as threatened. Ireland (2%) and Greece (2%) reported the lowest levels of species under threat for mammals and birds respectively.

In Australia, 13% of bird species are considered to be threatened. This is relatively low in OECD terms, with 22 other OECD countries having a higher proportion of threatened bird species. A quarter (25%) of Australian mammal species are considered threatened, the 11th highest proportion in the OECD.

See also the international comparison for Protected areas in the *Some international comparisons of progress* essay on page 189.

with the vegetation occupying the better soil and gentler slopes cleared first. For example, in 1996 79% of the Victorian south-east coastal plain had been cleared.[8] The most intensive agricultural land clearance has occurred in areas where crops or sown pasture have been planted.

Links to other dimensions of progress

Headline indicators of land affected by salinity, inland waters, air quality and atmosphere, and greenhouse gases each relate to areas of concern that affect our plants and animals as well as other aspects of progress. Oceans and estuaries and land use are also discussed. Another factor, discussed in the box on page 102, is changes to the patterns of fire.

Wildlife is important to many Australians – aesthetically, recreationally and culturally, particularly for many Indigenous Australians.

Biodiversity brings income and employment to Australia, through tourism for example (in 1995 half of international visitors went to a national park),[51] while agriculture relies on a variety of services provided by biodiversity to keep soil healthy, water clean and crops pollinated. But economic activity – including land clearance for agriculture and flow-on effects like salinity – has been a major reason for the decline of many species. Invasive species have also played a role.

The vast majority of land that has been cleared has been used in economic production, in particular agriculture, which has generated income and employment. But land clearance has economic impacts too. It can, for instance, lead to costs associated with reduced flood control, the improvement of water quality, or increased salinity and soil erosion.

About 7% of Australia's total greenhouse emissions are estimated to arise from land clearance (greenhouse gases are released from the burning and decay of vegetation and from the disturbance of soil which releases carbon). Clearing vegetation plays an important role in the spread of invasive species, land degradation and declining water quality (which are important to the environment and can impose costs upon the economy).

See also the commentaries *National income*, *Work*, *The natural landscape – inland waters, The natural landscape – land,* and *The air and atmosphere*

Endnotes

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The natural landscape – land

Progress and the headline indicator

Our soil resources are an important natural asset, and their degradation is a significant concern to Australian farmers, governments and the general public. There are several forms of soil degradation in Australia. Salinity, sodicity and acidity are all naturally occurring conditions of Australian soils, which have been exacerbated by agricultural activities. High salt levels in soils can cause the death of many plant species and sodic soils are prone to waterlogging. Acidity, or high concentrations of hydrogen ions in the soil also kills many plants. When left untreated, degraded soil reduces agricultural productivity, while salinity can damage buildings and infrastructure such as water pipes, roads and sewers. Degradation can also damage habitat for wildlife, kill micro-organisms that live in the soil, and harm the quality of our inland waters.

Ideally, the headline indicator would measure the land area affected by different types of degradation, and perhaps value their cost to agriculture, infrastructure and the environment. It might also measure whether the ways we use the land that lead to degradation are continuing. But many forms of degradation overlap one another, and there is no single measure of the area of degraded land in Australia. Moreover, some of these concerns (such as acidity) predominantly affect farm profits and so are primarily a financial concern to one part of the economy, rather than a key influence on the natural landscape.[1]

We focus here on dryland salinity which is linked to other forms of soil degradation, such as erosion. The impacts of salinity are also wider than lost agricultural production and include damage to water resources, biodiversity, pipelines, houses and roads.[2] Australia's rivers and landscapes are under threat to rising salinity, particularly in Western Australia, South Australia and in the Murray-Darling Basin. Some of the practices that have led to salinity have raised agricultural production and brought economic benefits. However, once established, salinity can have adverse effects on agriculture. In 2005, some 2.5 million hectares of land on farms were already affected by salinity, and there is potential for this to increase to 15 million hectares. Much of this is Australia's most productive agricultural land. The area damaged by salinity to date represents about 4.5% of present cultivated land, and estimated costs in 2000 include $130 million annually in lost agricultural production; $100 million annually in damage to infrastructure; and at least $40 million in loss of environmental assets. Salinity affects regions in all parts of Australia.[3]

The cost to agricultural productivity from salinity, estimated at $187m in 2000, is less than the cost of some other forms of degradation such as acidity, estimated at over $1b in 2000. But the cost of salinity goes further.[1] Salinity harms flora and fauna (primarily through loss of habitat), while saline

Salinity

Australia's soils are old and shallow, and are susceptible to degradation by agricultural activities. Even in a continent as dry as Australia, salinity occurs when there is too much water. Salinity occurs when the water table rises, bringing natural salts to the surface (in sufficient quantity, these salts are toxic to most plants). In the quest to prepare Australian soils for agriculture, trees were cleared by the billion.

Yet trees played a crucial role in maintaining the water balance in our ancient soils. It was the success in clearing trees that has led to the development of dryland salinity. (Irrigated-land salinity is caused by a similar effect – the application of excess water to land causes the water table to rise).[2] European farming practices which replaced native vegetation with shallow-rooted crops and pastures have caused a marked increase in the expression of salinity in our land and water resources.

Impacts of salinity

Salinity and rising water tables incur significant and costly impacts. Salt is being transported to the root-zones of remnant vegetation, crops, pastures, and directly into our wetlands, streams and river systems. The rising water tables are also affecting our rural infrastructure including buildings, roads, pipes and underground cables.

While Australia's salinity problem is significant, and is expected to increase as a result of past and present practices, different attempts to quantify the extent of the the problems have produced different results. In 2001, the National Land and Water Resources Audit estimated that 5.7 million hectares (not all of it agricutural land) had a high potential for the development of dryland salinity, and predicted this to rise to 17 million hectares by 2050. The 2002 ABS Survey of Salinity on Australian Farms found that about 20,000 farms and 2 million ha of agricultural land (rather than all land as reported by the NLWRA) showed actual signs of salinity.[5]

For many farms affected, dryland salinity has meant loss of productivity and income. There are also many off-farm impacts, the most significant of which appears to be the salinisation of rivers, which affects drinking and irrigation water (e.g. in Western Australia some surface water is already too saline for domestic use).[2]

Wagga Wagga is one of the worst affected towns in New South Wales, where salinity is damaging roads, footpaths, parks, sewerage pipes, housing and industry. Other provincial towns in New South Wales and Victoria (such as Dubbo and Bendigo), as well as western Sydney, are also affected. Predictions suggest that about 30 rural towns in Western Australia will be threatened by rising water tables by 2050.[2]

Dryland salinity also threatens biodiversity, through loss of habitat on land and in water. Areas near water are often worst affected because they occupy the lowest parts of the landscape where saline groundwater first reaches the surface. Areas of remnant and rehabilitated native vegetation are under threat in Western Australia, South Australia, New South Wales and Victoria.[2] In the Western Australian wheatbelt, salinity has caused a 50% decrease in the numbers of wetland bird species and 450 plant species are threatened with extinction through salinity.[4]

Assets in areas at high risk from shallow watertables or with high salinity hazard

	Year		
	2000	2020	2050
Agricultural land ('000 ha)	4 650.0	6 371.0	13 660.0
Remnant and planted perrenial vegetation ('000 ha)	631.0	777.0	2 020.0
Length of streams and lake perimeter ('000 km)	11.8	20.0	41.3
Roads ('000 km)	19.9	26.6	67.4
Rail ('000 km)	1.6	2.1	5.1
Towns (number)	68	125	219
Important wetlands (number)	80	81	130

Source: National Land and Water Resources Audit 2001, Australian Dryland Salinity Assessment 2000, NLWRA, Canberra.

water damages bitumen and concrete.[2] In 2000 some 1,600 km of rail, 19,900 km of road, 68 towns, and 80 important wetlands were at risk of damage from salinity.

The 2002 ABS Survey of Salinity on Australian Farms found that about 20,000 farms and 2 million ha of agricultural land (rather than all land as reported by the NLWRA) showed signs of salinity. Some 800,000 ha of this land could not be used for agricultural production.[5]

Land use: Agriculture

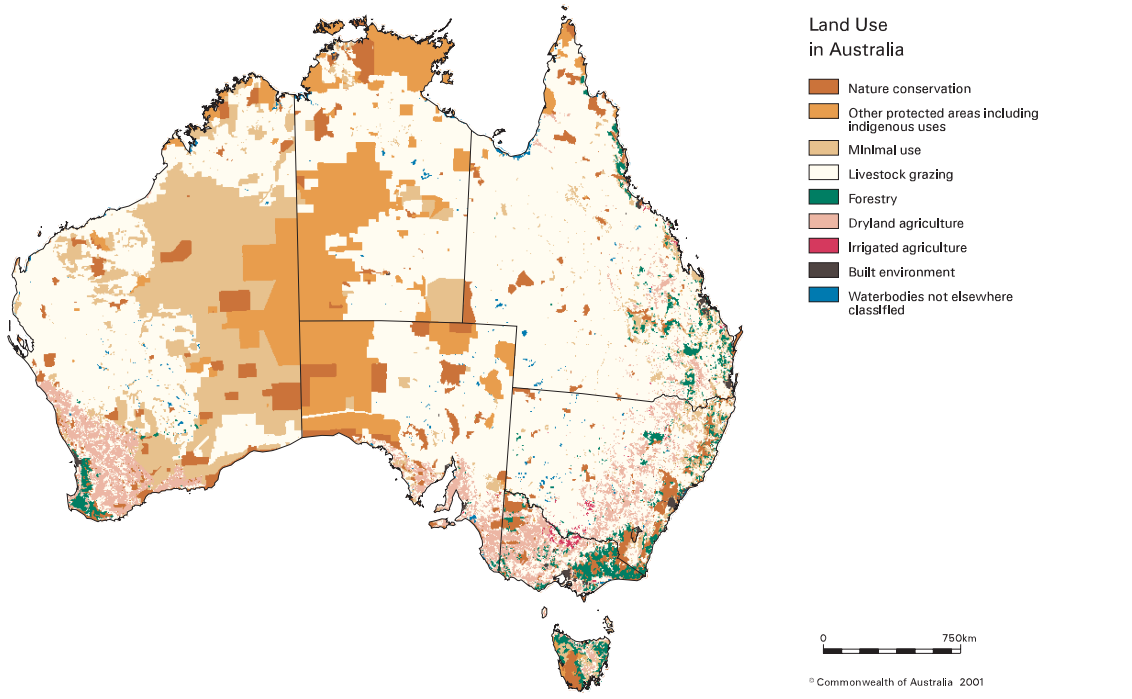
Since European settlement of Australia, land management has usually been focussed on specific human requirements such as agricultural production, urban development, transport, industry, recreation or biodiversity conservation.

Agriculture is the major form of land use in Australia. In 2004, 57% of Australia was used for agricultural activity: 3% for crops, 3% for pastures and grasses[6], with the remaining 52% of land holdings mainly used for grazing. Different agricultural activity affects the land in different ways, and the effects of land clearance (a necessity if crops are to be grown or pasture sown) are discussed in the *Biodiversity* section of *The Natural landscape* dimension.

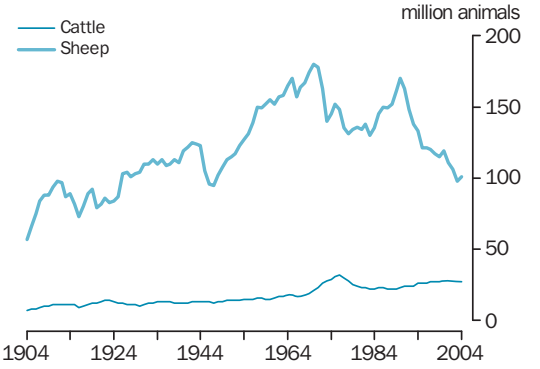
Once land has been cleared of native vegetation, the impacts of agriculture on the environment depend on the crops grown and farming practices used. While 26 million hectares (ha) of Australian land were used for growing crops in 2004, far more of Australia was used for grazing sheep and cattle.[6]

Until recently, interest in the links between changes in land use and the conservation of Australian biodiversity have focused on southern and eastern Australia where broad-scale clearing has been widespread.[7] There is now a growing appreciation of the effects of changes in land use on central, western and northern Australia.

Australian land use, 2001



Cattle and sheep numbers



Source: ABS Historical selected Agriculture Commodities, cat no. 7124.0.

Although the number of cattle has increased from 7 million cattle in 1904 to 27 million in 2004, the number of cattle has stablised in more recent times, increasing from 26 million in 1994. Numbers of sheep were 77% higher in 2004 than they were in 1904 (about 101 million sheep in 2004 compared to 57 million in 1904). But sheep numbers in 2004 were considerably lower than periods in the 1960s, 1970s and late 1980s. The national flock peaked in 1970 at almost 180 million animals.[8]

Grazing by stock and wildlife in arid and semiarid regions exerts a pressure on the land and is one of the major threats to native vegetation (along with grazing by feral animals and change in fire frequency).[9]

Altered fire and hydrological regimes and invasive species (including exotic grasses introduced in an attempt to improve pasture) may have had significant effects on the biodiversity of arid and semi-arid Australia. Increases in the number of large herbivores (such as kangaroos) have also had a direct impact. Domestic and feral livestock remove vegetation cover and break up the soil surface, exposing it to wind and water erosion, while an increase in pasture and numbers of watering points, and a reduction in dingoes, appear to have helped some species of kangaroos to increase in numbers in some areas. Kangaroos also put pressure on vegetation cover.

Land use: mining

There are many mines throughout Australia, and about 5,000 square kilometres or 0.06% of our total public land area is 'mining reserve' – Crown lands held in reserves for mining.[10] The extractive nature of mining operations create a variety of impacts on the environment before, during and after mining operations and are dependent on a range of factors associated with each mine.

It is difficult to assess changes in the effects of mining on the Australian environment over recent years. The amount of 'rehabilitation' to an area disturbed by mining can range from restoration, where an area is brought as near as possible to pre-mining condition, to recontouring and revegetating to a state that is non-polluting and compatible with environmental regeneration and community expectations.[11] A key industry initiative is Enduring Value – the Australian Minerals Industry Framework for Sustainable Development. This initiative builds on the Australian Mineral Industry Code for Environmental Management and seeks to maximise the long-term benefits to society that can be achieved through the effective management of Australia's natural resources.[12]

Land use: nature conservation reserves

Some 524,100 square kilometres or 6.9% of public land area in Australia are classified as nature conservation reserves throughout Australia.[10] These reserves (for example national parks, nature reserves and recreation areas) are Crown lands reserved for specific environmental conservation purposes such as protection of wildlife, protection of a type of habitat or preservation of an area with natural features of scientific or recreational value.

National parks are generally large areas of scenic or other natural significance to the general public. Three of the six Commonwealth National Parks, namely Kakadu National Park and Uluru – Kata Tjuta National Park in the Northern Territory and Booderee National Park in the Jervis Bay Territory are managed jointly by the Australian government with their Aboriginal traditional owners. The other three Commonwealth national parks protect unique island ecosystems within Cocos (Keeling) Islands and Christmas Island (located in the Indian Ocean) and the Norfolk Island Territory (in the South Pacific).

Land use: native forests

In 2004, there were an estimated 164 million hectares of forest in Australia (162.7 million hectares native forest and 1.7 million hectares plantation forests) – covering 21% of the continent. More than 13% of native forest was in nature conservation reserves. The largest areas of native forests in Australia are dominated by eucalypts (78%), followed by acacias (10%) and melaleucas (4%).[13]

Old growth forests are ecologically mature forests where the effects of disturbances are largely negligible. The total area of old growth forest in Australia is unknown. In Regional Forest Agreement (RFA) areas where assessments of old growth were undertaken, more than 5.2 million hectares, or 22% are classified as old growth and about 70% of these old growth forests are protected in nature conservation reserves, with some of the remaining 30% available for timber production.[13]

Nearly 22 million hectares or 13% of Australia's forest estate is formally protected in nature conservation reserves. This is an increase in the area of forest in nature conservation reserves of 22%, since the last national assessment in 1998. Forests are also conserved within leasehold land, multiple-use forest or private land (via covenants or other management arrangements).[13]

Plantation forests

Plantation forests are an important source of timber and currently supply more than half the logs for Australia's domestic timber requirements and exports. In 2004, Australia had more than 1.7 million hectares of timber plantations, which is approximately 1% of Australia's total forested area.[14] Of this total, 715,500 hectares (40%) were hardwood species and 1,000,600 hectares (60%) were softwood species.[13]

The area of plantation forests in Australia increased by 60% from 1995 to 2004. New planatations have been establised at an average rate of 75,000 hectares per year for the five years from 2000 to 2004.[14] About 25.4 million cubic metres of logs were harvested in 2003–04, of which about 60% were from plantations (the remainder were from native forests).[13] When planted on land that was previously cleared, plantations can bring environmental benefits, such as lowering the water table (and hence reducing salinity), reducing erosion, providing wind shelters or acting as carbon sinks to offset carbon dioxide emissions.

However, plantations (whether exotic or native) have vastly simplified ecosystems – with fewer species of plants and animals – when compared to forests that have matured over thousands of years. Plantations can also assist the spread of pests and disease, and can increase the risk of exotic species invading nearby areas of natural forest. Therefore we focus here on the progress of Australia's non-plantation forests.

Our forests act as carbon sinks (i.e. they absorb the greenhouse gas CO_2, as discussed in the commentary on *The air and atmosphere*). Forests are also used for many purposes, including recreation, biodiversity conservation, timber harvesting (the forestry industry and associated wood and paper manufacturing are a source of income and work in Australia, particularly for some towns), water catchment protection and honey production. All of these uses have impacts on the natural landscape, but the extraction of timber has attracted most attention.

Area of Australian forest types – 2004

Forest type	'000 ha
Acacia	16 488
Callitris	2 330
Casuarina	2 039
Eucalypt	127 025
Mangrove	749
Melalueca	7 056
Other	2 780
Rainforest	4 214
Total native forest	*162 680*
Hardwood plantation	715
Softwood plantation	1 001
Total plantation	*1 716*
Total forest	**164 396**

Source: Bureau of Resource Sciences, Australia's forests at a glance, 2005.[13]

Regional Forest Agreements

The Commonwealth government signed 10 Regional Forest Agreements (RFAs) with four state governments between 1997 and 2001. The 20-year agreements in Western Australia, Victoria, Tasmania and New South Wales cover regions where commercial timber production is a major forest use. They seek to provide a balance of the full suite of environmental, social, economic and heritage values that forests can provide for current and future generations.

The agreements set out to establish a forest conservation reserve system of nearly 10.4 million hectares. More than 8.5 million hectares are within formal dedicated conservation reserves, the remainder are within informal reserves for conservation purposes (such as special protection zones in State forests) and areas where values are protected by prescription (ror example: very rare values, values with a fragmented distribution, or values naturally occurring in a linear form such as riparian vegetation).[15]

The environmental impacts of timber harvesting are of greatest concern in native forests, where clearfelling and associated fire regimes frequently result in major changes to the species composition and structure of forests.[16] Forestry can damage soil structure, cause siltation of streams and rivers, and assist invasive plants and animals to spread.

One major impact of timber extraction is on animals that live in tree hollows. About one in seven of our vertebrate species (mammals, birds, frogs and reptiles) depend on tree hollows.[17] Suitable large hollows tend only to develop in trees older than 150 years, but sections of forests are typically logged every 55–120 years,[17] which means that large hollows will not develop in logged forests unless habitat trees are retained by forest management agencies.

The number of trees left standing to develop hollows has increased in recent years because of changes to the Codes of Forest Practice during the Regional Forest Agreement process (see box). In south-east NSW for example, only one hollow bearing tree was retained on every three hectares in 1991. By 1997, this had risen to 15 trees retained on every three hectares.[18]

Some differences within Australia

Dryland salinity coincides with those agricultural zones in which natural vegetation has been replaced – often many years ago – with land use systems that do not use water to the same extent as the natural vegetation. The largest areas of dryland salinity are in the agricultural zone of south-west Western Australia. Groundwater levels in this zone are still rising and over 4 million hectares have areas at risk; an area that could double by 2050. Large areas are also at risk of dryland salinity in South Australia, Victoria and New South Wales, mainly in the Murray-Darling Basin where groundwater levels are still rising. The salinity hazard assessment for the Northern Territory concluded it was relatively low. Also the bulk of the non-agricultural area of Western Australia, and far

western New South Wales were considered to currently have a very low salinity risk.[19]

Factors influencing change

Australia's soils are naturally saline in places. Salinity has been exacerbated by human activity, mainly agriculture. In some regions, problems originated over 100 years ago, from factors including excessive land clearance and large scale planting of pasture and crops that used relatively little water, pressures which remain today. In other areas salinity is coming to light after more recent land use changes. Because some of the problems began so long ago it is unlikely that they can be repaired easily. Salinity problems, for instance, only become apparent after long time lags, often 100 years or more (depending on the soil type).[2]

The National Action Plan for Salinity and Water Quality was endorsed in 2000 by the Council of Australian Governments. Under the plan, 21 priority regions have been targeted and governments and communities are working together to prevent, stabilise and start to reverse trends in dryland salinity, and improve water quality.

The National Dryland Salinity Program (NDSP) has been researching salinity for the past decade. In recent years, the focus of this research has shifted from salinity as largely an issue for agriculture, to its impact on infrastructure, and on integrating salinity management with other natural resource management strategies.[20]

Links to other dimensions of progress

In parts of Australia, land-related changes that result from human activites can take a long time to show themselves. The response time depends on a complex interaction of climate, geology and patterns of land use. Some forms of agricultural production, land clearance and other factors such as the weather can all contribute to salinity. National income and wealth are also affected, not just through the loss of agricultural production but also because of damage to roads, rail and buildings (the severity of these effects varies considerably from region to region). Salinity is a major threat to the health of many inland water systems. Soil erosion, another form of degradation, can affect inland waters too, as well as estuaries and inshore marine environments, such as the Great Barrier Reef.

Land clearing contributes to the enhanced greenhouse effect[23] and is also implicated in algal blooms and other problems associated with inland waters. Soil from agricultural land is washed into streams and dams, adding to the nutrient load.

See also the commentaries *National income*, *National wealth*, *The natural landscape*, *Oceans and estuaries* and *The air and atmosphere.*

Sustainable land management

Land is often managed for multiple benefits, such as agricultural production, biodiversity conservation, water quality, soil health and supporting human life. To ensure long-term sustainability, land managers need to consider economic, social and environmental factors. Sustainable land management means managing land without damaging ecological processes or reducing biological diversity.[21]

Biophysical degradation trends across agricultural and cleared regions of Australia indicate that many established land management practices are unsustainable. Many landholders are taking action to improve their practices in response to land degradation problems. However, some believe that change is needed on a still wider front to achieve long-term sustainability.

Since the late 1990s there has been substantial investment in landcare and bushcare programs. The Natural Heritage Trust has provided funding for environmental activities at a community level, a regional level and a National/State level.[22] Success is likely to depend on achieving consensus about the respective rights and obligations of individual landholders and the broader community, and development of mechanisms that provide for an equitable sharing of costs and benefits.

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The natural landscape – inland waters

Progress and the headline indicator

Water is fundamental to the survival of people and other organisms. Apart from drinking water, much of our economy (agriculture in particular) relies on water. The condition of freshwater ecosystems has a critical impact on the wider environment.

Freshwater is a finite and scarce resource in many areas of Australia. Some 80% of the country is classed as semiarid, making this the driest inhabited continent. However, our low population density means we have more water than many countries in per-capita terms.[1] At the same time though, we have one of the world's highest levels of water consumption per head,[2] and water supply and demand vary considerably across the country. In the tropics, for example, only a fraction of available fresh water is used by people. In other areas, such as the Murray-Darling Basin, pressure on water resources is acute.

Ideally the headline indicator would consider the health of Australia's freshwater ecosystems. Changes in the quantity and quality of all surface and groundwater would be measured, together with impacts from factors such as exotic species and changes to river flow. But such data are unavailable for much of the country, so we focus on water use, and consider the proportion of Australia's water management areas within which water extraction is thought to be sustainable.[3]

In 2000, the National Land and Water Resources Audit found that about 11% of Australia's surface water management areas were overdeveloped. Another 15% were approaching sustainable extraction limits (i.e. highly developed). Some 11% of groundwater management units were over-developed, and a further 19% were highly developed.[4]

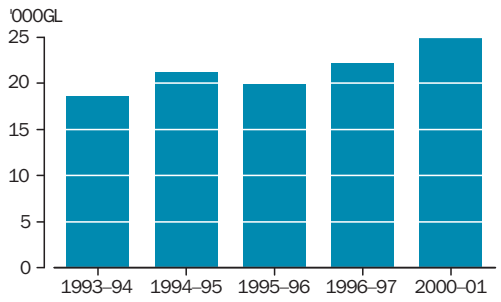
A variety of information from around the country points to a decline in some water resources. In some regions, the physical and biological condition of the rivers, wetlands and groundwater dependent ecosystems has been degraded by the extraction of water for agriculture, industrial, and household use.

Net water use

In 2000–01, Australian agriculture, industry and households consumed 24,909 GL of water. A further 47,522 GL of water was extracted from the environment, used mostly in-stream (mainly for hydro-electricity generation) and returned further downstream.[5]

Agriculture was by far the largest consumer of water in 2000–01, accounting for 67% (16,660 GL) of total water use in Australia. Households were the next highest consumers of water, accounting for 9% (2,181 GL) of water use. Total water use in households in 2000–01 was 19% greater than in 1996–97 (1,829 GL). The average household water use was 115 kilolitres/person in 2000–01, compared with 102 kilolitres/person in 1996–97. The water supply, sewerage and drainage services industry was also a significant consumer of water, accounting for 7% (1,794 GL) of water use, as was the electricity and gas supply industry which consumed 7% (1,688 GL), excluding in-stream water use for hydro-electricity generation.[5]

Net water use(a)



(a) Data not available for the years 1987–98 to 1999–2000.

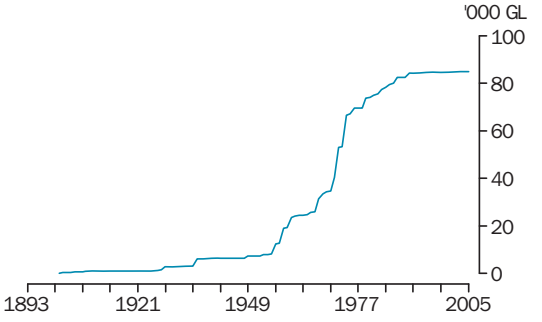
Source: Water Account for Australia, 1993–94 to 1996–97 and Water Account 2000–01 (ABS cat. no. 4610.0).

Water and Australia's development

Our rivers and groundwater resources played a major role in the early European settlement and development of Australia, often determining the location and viability of population centres and areas of agricultural production.[6] However, the high year-to-year and seasonal variability of Australia's river flows has led to the extensive regulation of rivers and groundwater resources to accommodate irrigated agriculture and domestic water demands.

The level of demand and reliability expected by Australian water users, combined with the high levels of evaporation in Australia, has led to relatively high water storage volumes. Following World War II, a massive nationwide program of dam-building has given Australia over 500 large dams with a storage capacity of 84,793 GL or over 4,000KL per person, the highest per capita capacity in the world.[6] Around 80 of these dams have a capacity of over 100GL (the volume of water contained in 100,000 Olympic-size swimming

Total water storage capacity of large dams



Source: *Water Account, Australia, 2000–01 (ABS cat no. 4610.0) and ABS Year Book 2006.*

Groundwater

Groundwater is water that occurs beneath the surface of the earth. It is available over most of Australia and in many parts of the country, especially the arid and semi-arid inland, it is of critical importance.[7] Greater regulation of surface water resources, opportunities for irrigated agriculture, and prolonged periods of drought have all contributed to our increased use of groundwater as a supplementary or alternative, water resource.[8] In 1996–97 approximately 5,000 GL of groundwater were extracted from groundwater sources.[9] Up to 4 million Australians are totally or partly dependent on groundwater for domestic water supplies.[10]

Groundwater and surface water systems are connected to each other to varying degrees in different parts of the country. Fundamental in all areas is the need to manage groundwater and surface water as two parts of one hydrological system.[11]

Household water use

In 2000–01, average household water use was 115 kilolitres/person. The majority of household water was used for outdoor purposes such as gardening (44%), followed by indoor uses, including bathrooms (20%) and toilets (15%).[5]

During the three years to mid-2004, the majority of Australia experienced drought conditions. This led to the introduction of water restrictions in most capital cities around Australia during 2002–03. Water restrictions varied from voluntary reductions of water use to mandatory restrictions. Sydney, Melbourne, Perth, Hobart and Canberra all experienced water restrictions during 2002–03. Brisbane had permanent restrictions on the times residents were able to use sprinklers.[12]

pools). While most of Australia's dam capacity has been built since 1970,[5] only one dam with a storage capacity of greater than 100 gigalitres was constructed between 1995 and 2005. Australia's large dam storage capacity is more than four times annual surface water diversions.[9]

Use of groundwater has also grown significantly since World War II and there are now more than 500,000 wells and groundwater assets valued at $6.5 billion.[6] Without groundwater much of inland Australia could not have been developed.

Effects of development

All river basins, like the Murray-Darling Basin, are naturally comprised of a set of interconnected physical, chemical and biological elements, which revolve around the flow of water. This interconnectedness and the limited amount of water in the basin means that the flow needs along the river, and the outcomes of activities and management decisions in one place have implications elsewhere in the basin. A 2001 assessment of the ecosystem services provided by the rivers, wetlands and floodplains of the Murray-Darling Basin estimated their value as $187.3 billion per annum.[13] Thus, these rivers are a particularly valuable resource. To provide the ecological goods and services that are fundamental to sustaining the uses to which they are put, these rivers need to be in good condition.

River condition has not been systematically assessed across Australia to identify the degree and extent of problems. In 2002, the NLWRA produced an Environment Index that assessed river condition depending on the nutrient and sediment in the water, the hydrological and catchment disturbance, and the condition of streamside vegetation.[14] The degree of modification depends on the extent of change from these factors. A moderately modified river, for example, has a catchment dominated by land uses that disturb the river, with associated water extraction, habitat changes (such as a reduction in streamside vegetation of 50%–75% of original cover) and loads of sediment or nutrients above natural levels.

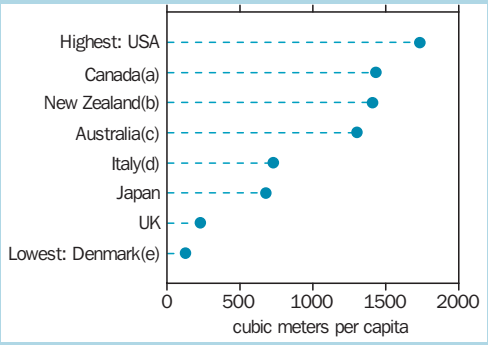
International comparison – water abstractions per capita

There is no OECD indicator available that is directly comparable to the headline indicator for water, i.e. The proportion of water management areas where use exceeded 70% of sustainable yield. An OECD indicator that illustrates the concept of intensity of water use is water abstractions per capita.

Freshwater resources are essential to human development and economic activity, and are also of environmental importance. Irrigation, industry and household water use are the drivers of demand for freshwater world wide. Water abstractions per capita is an indicator of the level of water use in a particular country. However, this indicator does not provide information on water quality. The water abstraction indicator is expressed as cubic metres per capita, per year.

The distribution and use of water resources varies greatly among the OECD countries. In the early 2000's the United States had the highest level of annual per capita water abstractions (1730m^3). Canada (1430m^3), New Zealand (1410m^3) and Australia (1300m^3) also had levels of per capita water abstractions well above the OECD average of 920m^3. Denmark recorded the lowest level of water abstraction per capita (130m^3) of all OECD countries.

Water abstractions per capita, 2000



(a) Data are for 1996. (b) Data are for 1999.(c)Data are for 1996–97. (d) Data are for 1998. (e) Data are for 2001.

Source: Environment at a Glance, OECD Environmental Indicators 2005.

The Murray-Darling Basin

The Murray-Darling Basin extends across one-seventh of the continent, from north of Roma in Queensland to Goolwa in South Australia and includes three quarters of New South Wales, all of the ACT and half of Victoria. It is the catchment for the Murray and Darling Rivers and their many tributaries, containing more than 20 major rivers, as well as important groundwater systems, and has a population of nearly two million people.

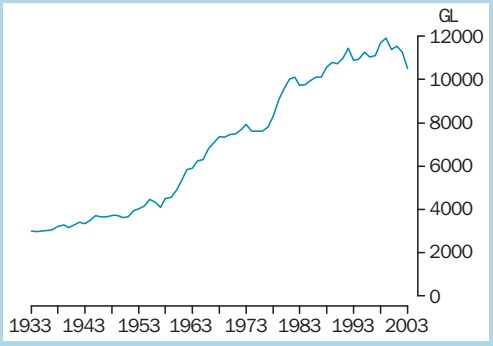
The Murray-Darling Basin is an important source of fresh water for domestic consumption, agricultural production and industry.[17] It generates about 40% of the national income derived from agriculture and grazing. It supports one quarter of the nation's cattle herd, half of the sheep flock, half of the cropland and almost three-quarters of its irrigated land.

Much of the Basin's natural resources are of high environmental value. Its wetlands are extensive, a number of which are recognised under the Convention on Wetlands of International Importance (otherwise known as the Ramsar Convention).

In the last 100 years, the Murray-Darling Basin has been transformed by the construction of major water storages on the rivers. The total volume of water storage capacity of major dams in the Basin is nearly 35,000 gigalitres. These storages have made it possible to store water during wet periods and release it as needed during summer or in droughts. Water diversions (mostly for irrigation) have increased steadily since 1930. The amount of water diverted increased substantially in the early 1950s. More recently, average annual diversions between the periods 1989–1993 and 1999–2003 fell by 3%, largely driven by a decline in water use in Victoria and New South Wales (where use fell by 13% and 7% respectively), partially offset by an 8% rise in use in South Australia and a 9% rise in Queensland.

In the late 1990s, environmental degradation and increasing water demand led to a 'Cap' on river diversions in the Murray-Darling Basin, aimed at achieving a better balance between production and the environment. In 2003, 500 GL of water was made available for environmental flows as part of a major initiative called 'Living Murray'.

Water diversions(a), Murray-Darling Basin



(a) Data smoothed using a 5-year moving average.

Source: Data available on request, Murray-Darling Basin Commission 2004.

Some 90% of Australian rivers were assessed. Among these rivers, the index found that:

- 66% of river length was moderately modified
- 19% was substantially modified
- 1% was severely modified.

Two-thirds of river length assessed in the Northern Territory is in largely unmodified condition, as is about two-fifths of Tasmanian river length assessed. In the other states and territories, less than 20% of assessed river length was unmodified.[14]

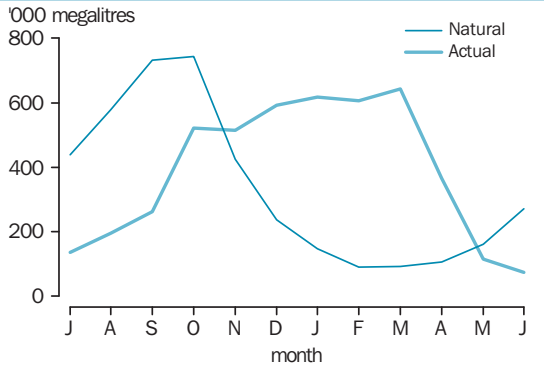
While at a national level only 15% of the nation's groundwater resources are being used, local overuse is becoming a major concern, as it is often not possible to restore a ground water system to its natural state. This overuse is creating resource degradation through processes such as depletion, salt intrusion and pollution.[15]

The removal of streamside vegetation allows increased sediment into the river, which can add nutrients and pollution harmful to aquatic species and overall river health. Vegetation is degraded in many catchments from clearing, grazing and salinity: in some areas of Western Australia, for example, 48% of rivers and 34% of creeks have lost much of their streamside vegetation and fewer than 10% of wetlands have healthy fringing vegetation.[16]

Irrigation and tree clearing have caused rising water tables and increased the salt in groundwater in many places. This increasing salinity is a threat to the health of our aquatic ecosystems and our water supplies.[10] Erosion from land surfaces and stream banks has also resulted in widespread degradation of aquatic habitat.[13] In addition, dryland salinity is seen as a growing problem that is threatening agricultural production, infrastructure and the ecological integrity of the rivers.

Drinking water for most of South Australia and many inland towns in New South Wales is at risk from increasing salinity.[10] If salinity is not

Natural and actual flows per month, River Murray at Albury — 1999–2000



Source: Murray-Darling Basin Commission.

Algal blooms

Algae, a natural component of aquatic environments, are an important part of the food chain, and even when they are abundant this is not necessarily a problem. Often a proliferation of microscopic algae can have beneficial effects on fisheries and aquaculture industries such as oyster or mussel farms by increasing the amount of food available.

However, there are times when algal blooms, the rapid excessive growth of algae, can poison the water, affecting people, wildlife and livestock. Some types of algae can cause liver damage or tumour growth, and skin and eye irritation.

The amount of phosphrous present is a key factor in whether or not an algal bloom develops, but blooms also depend on a number of other factors, including flow rates, turbidity, light, salinity and nutrient loads. The extra algae in the water outcompetes other plant life and absorbs oxygen from the water. Aquatic animals die and create more phosphate for the algae, intensifying the problem. They are most common in storages, lakes, wetlands and stretches of rivers that have still waters and are enriched with plant nutrients, nitrogen and phosphorus (these substances can enter water from fertiliser run-off, fish farms, sewage and stock manure as well as from urban storm water). They are a significant problem in reservoirs and other water storage areas because of the increased costs of treatment, management and sometimes provision of alternative water supplies.

Algal blooms are not a new phenomenon but they are now far more common than they used to be. Blooms are often indicative of a decline in the ecological health of freshwater systems, and can occur in urban or rural areas. It has been estimated that freshwater algal blooms (excluding blooms in estuarine or coastal waters) cost Australian water users between $180m and $240m annually.[21]

controlled in the River Murray, Adelaide's drinking water has been predicted to exceed guidelines for salinity on two days in five by the year 2020.[10]

Nationwide, 80 of 851 nationally important wetlands are affected by salinity, and this is predicted to rise to 130 by the year 2050. Many of these wetlands contain species at risk from salinity.[10] The causes of salinity and its impact are discussed in the commentary *The Natural Landscape – Land*.

Water resource development has altered the seasonal characteristics, rate and variability of flows in many river systems. For example, the flow of the River Murray through Albury would naturally peak in spring and be at its lowest in February. Now water is stored in dams in winter16b Air and atmosphe released for irrigation in summer and autumn. As a result, peak flows, which are reduced, occur in summer, with minimum flows in the winter.[18] These changes resulted in inappropriate water regimes for a number of ecological communities, including Barmah-Millewa forest, with unseasonal and unnatural wetting and drying having marked effects on plant and animal communities with many in-stream habitats, floodplains and wetlands becoming permanently flooded.[19] This, in tandem with the overall decrease in flows, led to a reduction in the available habitat and also reduced the reproductive cues of many aquatic species.[19,20]

The release of cold water from storages has also affected the reproductive cycle of many aquatic species,[18] while changes in flow patterns have helped exotic species, such as carp, to spread and out-compete native species.[20] Reduced flows are one factor that can lead to more severe algal bloom outbreaks because of stagnation (see box). A water management strategy has been developed for the Barmah-Millewa forest which allowed for the usage of an environmental water allocation (EWA) (100 GL / year). The release of the EWA is normally timed to supplement floods already occurring in the forest, to allow high water levels to remain longer in the forest by slowing the recession of the flood. In 2000, it prolonged the forest flooding and created suitable conditions for the successful breeding of a wide number of species.[21]

Native freshwater fish

Over the past 100 years, populations of native fish species have suffered serious decline in both distribution and abundance. Many factors have contributed to the deterioration of fish habitat and native fish populations. These include significant

River condition

Use of Australia's land and water places pressures on the river systems. In 2001, the National Land and Water Resources Audit (NLWRA) assessed river condition for those rivers in the more intensively used parts of the country. The data focussed on the diversity of macroinvertebrates (bugs) that inhabit different stretches of river. Because these animals are sensitive to changes in river catchments (e.g. land clearing) and to changes in the condition of the river (e.g. water quality), they are good indicators of river condition.

The data showed that 23% of assessed sites were significantly impaired, having lost 20–50% of macroinvertebrates expected to be present. A further 6% were severely impaired (having lost 50–80% of expected macroinvertebrates) and 2% were extremely impaired and had lost more than 80% of expected macroinvertebrates. The majority of impaired rivers were in New South Wales.[13]

River condition (biota index), by state

	% of sites assessed where biota was		
	Significantly impaired	*Severely impaired*	*Extremely impaired*
	%	%	%
NSW	34	13	3
Vic.	20	3	1
Qld	17	2	1
SA	12	1	4
WA	29	6	1
Tas.	20	3	2
NT	10	2	. .
ACT	29	7	. .
Aust.	**23**	**6**	**2**

Source: National Land and Water Resources Audit, 2001.

Wetlands

Australia probably has the most variable wetland and floodplain systems in the world, reflecting the nature of our climate, particularly in the inland. They protect our shores from wave action, reduce the impacts of floods, absorb pollutants, purify our water, and provide habitat for animals and plants. They also form nurseries for fish and other freshwater and marine life and, because of this, they are critical to Australia's commercial and recreational fishing industries.[29] According to the international Ramsar Convention, Australia currently has 64 Wetlands of International Importance, covering a total of approximately 7.3 million hectares.[30]

Wetlands include swamps, marshes, billabongs, lakes, saltmarshes, mudflats, mangroves, coral reefs, fens, peatlands, or bodies of water – whether natural or artificial, permanent or temporary. Water within these areas can be static or flowing, fresh, brackish or saline.

The National Land and Water Resources Audit (NLWRA) reported on the condition of 851 nationally important wetlands in 2001. Some 58% of the wetlands assessed were in good condition (recovery in short-term with minimum intervention) and were mainly found in northern and eastern Australia. Those assessed as near pristine occurred in several subregions – on Cape York Peninsula, Tasmania and parts of the Channel Country. Those in the rangelands and south-west of Western Australia, and most of New South Wales were in fair (recovery requires significant intervention) or degraded (recovery unlikely in the medium term) condition.

Changes in the condition of wetlands were also assessed. The condition of wetlands in 59% of subregions was static and was declining in 37% of subregions assessed in 2001. The NLWRA estimated some 50% of wetlands to have been destroyed since European Settlement.[13]

Riparian zones (riverbanks) were assessed as fair in 38% of subregions and degraded in 31% of subregions. The trend in the condition of riparian zones across 73% of Australia was one of decline, with over grazing, exotic weeds, changed water regimes, increased fragmentation, feral animals and changed fire regimes all listed as common threats.[13]

changes to water flow, thermal pollution, the degradation of in-stream and riverbank habitats, barriers to fish passage, the introduction of exotic fish species and fishing pressures.[23] The extent of each threat varies according to differences in water resources and urban and agricultural development. While fishing has played a role in the decline of fish populations, the modification and degradation of fish habitats have had the most substantial impact.[24]

Of over 200 native species of freshwater fish in Australia, the Commonwealth lists 11 species as endangered and 10 as vulnerable to extinction.[25] Some 35 exotic fish species have become established in inland waters, with eight identified as having a significant impact.[10] Many were introduced into Australia for ornamental or fishing purposes.[26] Some, such as trout and carp, are harming native fish. Carp feed by uprooting and killing aquatic plants which native species feed on. The carp thereby disrupt the river bank and stir up sediments which free nutrients that enhance toxic algae (they also contribute to algal blooms by preying on the species which feed on the algae). This also reduces the number of aquatic invertebrates which native fish feed on.[27]

Estimates of the present levels of native fish communities in the Murray-Darling Basin are 10% of the pre-European settlement level. This level is not considered to be sustainable in the long-term.[23] In order to address this decline, a Native Fish Strategy has been developed by the Murray-Darling Basin Commission, which aims to rehabilitate native fish communities back to 60% of their estimated pre-European settlement levels within 50 years.[23]

Some differences within Australia

Rainfall, or the lack of it, is the single most important factor determining land use and rural production in Australia. Agriculture was by far the largest consumer of water in 2000–01, accounting for 67% of total water use in Australia. Australian agricultural establishments applied 10,404 GL of irrigation water to 2.4 million hectares (ha) of crops and pastures in 2002–03. The largest volume of irrigation water that was applied was on pastures for grazing purposes (2,827 GL), followed by cotton (1,526 GL), sugar cane (1,293 GL) and cereal crops for grains or seed (1,002 GL). Rice required the highest application rate of irrigation water (14.1 ML/ha), followed by cotton (6.5 ML/ha).[28] The majority of Australians (80%) rely on mains or town water for drinking. This reliance on mains or town water for drinking is more pronounced in the capital cities (89% of households in 2004) than outside capital cities (67% of households).[12]

Protecting Australia's inland waters

Although there is still much to learn, research and reporting into Australia's water resources by the National Land and Water Resources Audit, the CSIRO – Water for a Healthy Country Flagship, the ABS *Water Account, Australia*, State of the Environment Reports and state and territory water management agencies are improving our knowledge of this valuable resource.

In 2003, the Council of Australian Governments (COAG) agreed to review its 1994 water reform framework through a new National Water Initiative which plans to set the water policy agenda for the next ten years and beyond. The agreement was signed in 2004 by the Australian Government and all state and territory governments, with the exception of Western Australia.

The National Water Initiative aims to:

- encourage water conservation in our cities, including better use of stormwater and recycled water
- ensure ecosystem health by implementing regimes to protect environmental assets
- improve the security of water access entitlements, including the return of allocated systems to sustainable allocation levels, and
- ensure that water is put to best use, involving clear rules for trading, robust water accounting arrangements and pricing based on full cost recovery principles.[32]

Factors influencing change

Australia is the driest inhabited continent, even though some areas of Australia receive annual rainfall of over 1,200mm. Rainfall in Australia is variable and uneven. Patterns of low rainfall vary over the years, and so climatic variation is a major influence on water availability. Over the longer term, population growth has led to increased water use, but its contribution has been small in recent times. The main changes since the 1990s have come from increased agricultural and industrial use (to a large degree, these are independent of population growth). Most of the 12% rise in total water consumption between 1996–97 and 2000–01 was due to the agricultural sector. However, more recently (2002–03) due to drought conditions, a lower level of water use by this sector has been apparent.[31]

Changes in economic activity affect water use, with each industrial sector using water according to its size and needs, so the economy's industry composition is important. New industries, such as those in the growing service sector, use water much less intensively than agriculture, manufacturing and mining, and so the economy as a whole is now less reliant on intensive water use. Meanwhile, a greater focus on efficient use of water has led to an increase in the volume of waste water re-used. In 2000–01 approximately 517 GL of water were reused, up from 134 GL in 1996–97.[5] At less than 4% of the total water supplied by water providers in 2000–01, this figure has the potential to grow significantly.

Across Australia, catchment land use and diverting water are considered the most serious changes to the ecological condition of Australia's rivers, wetlands and groundwater dependent ecosystems. Australian governments are working on a framework for 'water reform' aimed at halting degradation in inland waters and minimising unsustainable use. Its main elements include provisions for water entitlements and trading, environmental requirements, institutional reform, water pricing, research and public education.

Links to other dimensions of progress

Economic production, in particular agriculture, is the major user of water. Water degradation is strongly linked to inappropriate land management (often in the past) such as land clearance and forms of soil degradation, while much of our biodiversity depends on healthy freshwater ecosystems.

The quality of our inland water and changes to the land are linked to one another. For example, increasing river salinity caused by dryland salinity can result in water becoming too saline for drinking or irrigation. It can also kill streamside vegetation. This, in turn, can increase erosion in river banks, which can cause further deterioration in water quality and loss of aquatic species.

Contaminated water can affect the health of ecosystems, people and livestock, while managing contamination involves a significant economic cost (e.g. the total costs of managing algal blooms were estimated to be in the order of $200m a year during the late 1990s).[22]

See also the commentaries *Health, National income*, *The natural landscape – biodiversity*, *The natural landscape – land*, and *Oceans and estuaries.*

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